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# THE SCIENTIFIC MONTHLY

## SEPTEMBER, 1923

## THE UTILITY OF SOCIAL NUISANCES

By Professor KNIGHT DUNLAP
THE JOHNS HOPKINS UNIVERSITY

USING the word "nuisance" in its literal meaning of something harmful or injurious, I shall include under the term "social nuisance" any organized activity or propaganda which is of such nature that if it should succeed or prevail generally, it would produce social damage, either through a retrograde movement or the inhibition of progress in practical conditions of life, in the status of general knowledge or in social ideals. I shall raise the question whether these social nuisances, so long as they do not succeed or so long as they succeed in influencing only a safely small minority, do not actually have utility in forwarding the very things which they aim at obstructing or in accelerating the removal or suppression of the forces and conditions which they represent.

I wish to examine briefly, therefore, several familiar social nuisances and to inquire into their probable evil effects and possible good effects socially. While, for convenience and clearness, I shall state my points dogmatically, I wish it understood that in reality I am hoping merely to raise questions; and I find that the most certain and effective means of arousing in an intelligent audience a healthy questioning of theoretical statements is to make them bluntly dogmatic.

One of the most striking examples of a nuisance which has had a distinctly beneficial effect is Christian Science. Christian Science, if it should succeed in its aims, would not only abolish medical practice and remove the curative and sanative measures which have in modern times made so large a contribution to the amelioration of the conditions of life generally, but it would also abolish scientific research and stop progress in engineering and in the arts. It is true that the most persistent attack of this cult is upon medicine and that it for the present temporizes in regard to other applications of chemistry, physics and biology. Christian Science temples

are of material stone and brick, erected by the use of material means, and even heated with material coal and lighted by electricity: Christian Science farmers do not scruple even to apply chemical fertilizers to the soil. One may be astonished at this and wonder why the use of "material" means to stimulate the eye and to assist the bodily heat-regulating mechanism are not as wicked words of "mortal mind" as are the application of "material" means to relieve indigestion and to stimulate the heart. One may stand aghast at the sublime inconsistency of a congregation of Christian Scientists of a summer evening cooling themselves with palm leaf fans; but we must remember that Christian Science has no worries over logical consistency, but dismisses logic as an evil work of "mortal mind."

Furthermore, these inconsistencies are not more egregious than certain temporizations in regard to medicine itself. By a general dispensation, Christian Scientists patronize dentists and obstetricians, although in theory these forms of medical assistance are in no different class from internal medicine, and in the thoroughgoing application of the principles of the cult no "material" means should be used to accomplish any result, the application of fertilizer to the soil being as great a lapse from "divine mind" as the application of quinine or a porous plaster to the animal body.

These inconsistencies cease to be sources of astonishment when we remember that the real animus of Christian Science, aside from its strictly religious and ethical points, is not against science, and really not even against medicine as a whole, but against *drugs*, or, in Christian Science terminology, against *materia medica;* and that the vagaries of the Christian Science theory with regard to the phenomenal world are merely naïve attempts to justify this animus, and its larger generalizations, even those against surgery, are necessarily only verbal and largely ignored.

Although we must admit that the effects of Christian Science have been very bad upon many of its adherents, both physically and mentally, we must nevertheless admit that it has contributed very substantially to the progress of medicine, and that society owes to it a debt of considerable magnitude. A generation ago, American medical men were in the habit of prescribing a great many drugs. Many of us can remember the various and nauseous decoctions and powders that were administered by general practitioners. In fact, if the physician attending a sick man did not give him several kinds of medicine, the patient's family would hardly believe that the medicine man was doing his duty. A few of these medicines so generously administered were proven specifics: quinine for malaria; mercury for syphilis; ipecac to produce nausea;

with of course a long line of cathartics and laxatives, many of them of conjectural advisability. But the majority of the syrups, tinctures, extracts and other preparations had no more demonstrable efficacy in the general run of cases than had the potions and philters of the more primitive medicine of the middle ages and of savage tribes. The routine administration of medicines belonged strictly to the domain of magic and not to science. This type of medicine received its *reductio ad absurdum* in homeopathy, but its death blow was given by Christian Science. When patients unmistakably got well, not merely with the infinitesimal doses of the homeopathists, but even with nothing but the incantations read from Mrs. Eddy's book of magic, the efficacy of the conventional slops began to be doubted, not only by the public, but by the medical profession. The more intelligent and progressive leaders of medical science, including in America such men as Sir William Osler and Llewellys F. Barker, found, therefore, a suddenly fertile field for their teachings. Physicians generally began to listen to scientific men in medicine, and to largely abandon the pill and powder and spoonful treatment, and to depend largely on common sense diet, good nursing and scientifically demonstrated remedies; and they speedily beat the Christian Scientists at their own game. Even to-day, when a great many specifics, antitoxins and other medical agents have been scientifically established, the amount of medicine administered by mouth is very small as compared with that given a generation ago. While it is true that Skoda and his followers in Europe, and Osler and his coadjutors here should have the maximal credit for this progress, we should not overlook the fact that homeopathy and Christian Science have aided them materially in putting medicine on a scientific basis.

Another nuisance which has menaced medical practice and scientific research is the antivivisectionist movement. In some places the antivivisectionists undoubtedly have cramped medical research and will cramp it more. But I suspect that, on the whole, animal experimentation has actually been helped by the antivivisectionists. This assistance has been rendered through the general care which they have forced upon physiology and pathology: care to do the necessary animal work under the most humane conditions, and care to avoid unnecessary work of a merely demonstrational kind; and care to explain to the public the necessities of the research. In this way, if animal experimentation has not actually strengthened its hold upon the public, it has at least obviated a very serious weakening of the hold which would have led to an uncontrollable landslide against it.

In another way the Christian Scientists, antivivisectionists, and more especially certain other antimedical movements, such as osteopathy and chiropractice, which would be disastrous if they should succeed, have been of social value. The tendency to regulate the lives of individuals in the most autocratic way has not been alone a tendency of the moralists, but has been shown at times by groups in the medical profession. Without denying that a minimal amount of regulation is necessary, we must also admit that the tendency to regulate always runs ahead of the knowledge requisite for proper regulation. In view of the general apathy of the public, which rarely awakens as a whole to the need of protecting its liberty until its liberty is taken away, it would undoubtedly be unfortunate if we had no continuous nucleus of antagonism to every new form of health and hygiene autocracy which appears. This nucleus supplied by the antimedical group, constantly watchful, constantly active, and having considerable financial backing, has helped to forestall movements which would have been not only inimical to the public welfare, but also to the progress of medicine itself. In legislative halls, these groups watch carefully not only encroachments upon their own fields of graft, but also other encroachments which extend the autocratic power of the medical profession. I have no doubt that, if these interests had not stood in the way during the last ten years, the openly expressed aim of certain medical agitators—to put the mental examination of school children in the hands of M. D.'s exclusively and to prohibit trained psychologists from administering the Binet-Simon and other tests which they have created—would have reached a successful issue already.

Aside from the medical problems, there is at present another nucleus representing a point of view and a propaganda which would have most unfortunate results if successful, but which in its present condition is essentially valuable. This nucleus is constituted by the pacifists. Undoubtedly the pacifists were a great nuisance during the war. It is obvious that if they had had their way then, they themselves would now be listed for military service under the German Imperial Government (or their sons would be), and their attempts to preach pacifism would be suppressed by firing squads. Nevertheless, their existence during the war tended to moderate extreme measures which would have been disastrous at that time and to-day is an effective force against the encroachments of militarism in various forms. I believe we would be much worse off than we are to-day if we had no unreasonable and violent pacifists. But, unfortunately, the same principle works here also in another way, and just as the fanatical advocates of "peace at any price" during the war threatened to be of direct assistance to militarism, so they have helped militarism since by helping to defeat the

league of nations and promoting entanglements in the way of disarmament treaties, whose pernicious effects are already being shown.

Another group of propagandists who constitute in many respects an intolerable nuisance have also been of social value in somewhat similar way. Whether we Americans shall succeed or shall not succeed in maintaining our rights of free speech and constitutionally guaranteed rights to work for changes in the laws and government remains to be seen; and while it may be that the existence of the so-called "Red" propaganda intensifies the efforts of those who are attempting to destroy our constitutional guarantees, nevertheless I believe that the public attention brought to these efforts greatly facilitates our chances of salvation, and that without the conflict with the "Reds" we would be in much more danger of having our liberties taken from us bit by bit, not awakening to the despoliation until it should be complete.

Another nuisance of a somewhat different sort, but no less a nuisance, has been the antievolution propaganda of the "fundamentalists" which has reasserted itself during the last few years. This propaganda is obviously a highly organized and well-financed effort for which the silver-tongued Nebraskan is merely a mouthpiece. If this propaganda should succeed, it would not merely destroy freedom of investigation and freedom of discussion in regard to the doctrine of evolution, but would be a significant and momentous backward step toward the medieval ecclesiastical control which has had such terrible effects in the past in many directions of science. This propaganda has indeed attained a measure of success in a few places. But we need not fear its general success, and in the meantime it has done a vast amount of unintentional good. Three years ago only a small percentage of the general public had much accurate information about the doctrine of evolution as actually taught by the biologists, and all sorts of wild evolutionary doctrines were inflicted upon the public by unofficial would-be scientists to the prejudice of the real theories. Since the recent agitation commenced, there is vastly more popular knowledge in this whole matter. The expository books which have been well written by Conklin and other leaders in biology have been bought in vast quantities. Not only have these books been extensively read, but magazine articles by qualified writers have also been widely read, and public lectures by authorized biologists and geologists have been largely attended. This increase in knowledge, I believe, far outweighs the temporary adverse effects of the propaganda, and I do not doubt that the progress of acceptance of the doctrine of evolution has been greatly forwarded; and also that the promulga-

tion of the doctrine of evolution will be much more cautious and conservative, and hence more acceptable.

For a number of years, an influential group, for whom a well-known and vulgar evangelist was the figure-head, carried on a propaganda which finally attained to the level of a well-marked social nuisance. This movement was deplored by the better educated members of the ministry of practically all denominations; but the propaganda had such force and financial backing that the majority of these ministers did not deem it advisable to oppose it openly. It has been alleged that the general purpose of the propaganda was perhaps political: that it was financed by men who were interested in keeping labor quiet and who believed that "old-time religion" would be a good narcotic. This theory may or may not be true; but it is apparent that the propaganda did not attain a large measure of success in this direction, and it is of course possible that this failure was largely responsible for its decline.[1] Superficially, the results of the movement were unquestionably bad. Religion was held up to ridicule and lost not only in spiritual value, but also in prestige wherever it was soiled by this movement. But on the whole, perhaps, the movement seems to have done good. This type of "evangelism" was but a more flamboyant, more vulgar and more lucrative manifestation of activities which had long been widespread in the United States, and the focussing of public attention on the evils involved and on the comparative lack of valuable results has been extremely useful. Apparently, in those localities in which this mockery on religion was exploited, there has been a marked lessening of the minor activities of the same type, and I believe that the final effect of the movement has been an acceleration of religious progress through the inhibiting and discrediting of the forces and tendencies on which the propaganda built.

By many individuals to-day prohibition is considered a social nuisance, and by some it is magnified to the position of the greatest of social nuisances. It may be that the antiprohibitionists are right. I am not interested in either side of this argument, but wish to point out that, even if prohibition is a great nuisance, it may be nevertheless true that it has great social value. As a matter of fact, the question of the limitation of personal liberty is a very serious one. Few people to-day would contend that it is possible to maintain an organized society without a considerable degree of such limitation. Many persons claim, however, that this limitation should be reduced to its lowest terms: that we should limit the activities of individuals only in so far as these activities, if not limited, would to a

[1] This propaganda has again flared up in the south, and will doubtless have a beneficent cathartic effect upon religious conditions there, as it had in the north.

greater extent limit the activities of others. This has been supposed to be the fundamental principle of the Democratic party in the United States, scandalously as this party has flouted the principle from time to time.

The question of prohibition is bound up with the question of the suppression of the traffic in drugs, of the suppression of the traffic in women, of the suppression of gambling and many similar paternalistic or socialistic regulations. One result of prohibition has been a renewed questioning of this whole situation—a questioning as to the theories and means by which individuals may be deprived of their liberties and the extent to which such deprivation can justifiably go. While it is through prohibition that our attention has been so forcibly called to the evil effects of general lawbreaking, to the questionable value of laws which can not be generally enforced, and the egregious effect of laws which are enforced only on the poor and those without political or financial pull, our analysis does not remain on prohibition alone in regard to these points. We have at last waked up to the fact that in many states (Maryland, for example) we have been long afflicted by Sunday laws which are universally broken, even by those who have banded themselves together in the "Lord's Day Alliance" to promote their enforcement; and which, when they are enforced at all, are enforced only on foreigners and others who are low in the social or economic scales. We have awakened to the fact that our laws against gambling are of the same nature: that we raid the African crap game, and the card game in the foreign quarter, but that we would never think of raiding bridge games in fashionable residences or poker games in influential clubs. We have awakened to the curious fact that large numbers of the same people who are violently opposed to the legal suppression of the dissemination of information concerning the manufacture of home brews and the sale of apparatus for such manufacture are also as violently in favor of retaining the present laws against the dissemination of information concerning means of contraception and the sale of instruments and materials for such uses.

Whatever we decide on the question of the percentage of alcohol which shall be permitted in beverages, whatever we decide about the drug traffic (and we must remember that bootlegging in narcotics has a volume in the United States far exceeding the bootlegging in alcoholic beverages), whatever we decide about birth-control, we shall probably, within a few years, advance our whole political and social attitude towards the application of restrictive personal legislation, and it may even be that we shall be able to dissolve the iniquitous union of church and state now existing in many parts of

the United States in defiance of the Constitution: an outcome which would far outweigh all of the alleged evils which prohibition has brought upon us.

There are several social nuisances whose evil influences and whose ultimate utility may both be open to doubt. In the case of college athletics, for example, it is difficult to make out at present the relative values of the good and evil effects, although I am optimistic here also. As at present organized, college athletics defeat the very purposes for which they were presumably introduced, namely, the offering to students of facilities for taking the proper amount of physical exercise and relaxation, and inducements to make use of the facilities. While there can be no question as to the desirability of this program, we know that college athletics work in exactly the opposite direction. The great urge is upon men to "come out" for teams and assist in upholding the standing of their college in athletics, and the whole emphasis is on "beating" the rival colleges. Hence men are not wanted on training squads unless they have superior physical capacity and if they can not give to the training more time than the serious college student can really afford. The result is that the very students who most need physical exercise are excluded from these activities; and the financial strain of the organizations for the production of winning teams prevents the establishment of the facilities for reasonable general games and athletics. Moreover, a certain by no means negligible number of students who might benefit from their college work, but who have superior physical capacity, are forced into athletics by student opinion, or are drawn in by their natural inclinations and the surrounding enthusiasms, and come to grief in their studies, either getting little out of college or being eliminated entirely. This waste of good college material must be given a large weight in the debit column of college athletics. On the credit side, we, of course, must put the development of the group spirit, which is an advantage in itself, but which perhaps could be realized just as advantageously in the large universities through the maintenance of racing stables. Intercollegiate horse races would, from many points of view, offer superior advantages for the formation and maintenance of college spirit, and the stables would not cost any more than the football teams cost these universities, and furthermore would not entail the sacrifice of capable students to the intercollegiate Moloch. Another credit which is closely connected with the formation of group spirit is the offering of extra-curricular topics of interest and conversation; and athletics as now organized does offer this topic, even to the majority of students whose active participation is limited to buying tickets, sitting on the bleachers and smoking cigarettes.

Students, in their periods of relaxation from academic work, necessarily turn to non-academic topics of discussion; and team standings, scores and activities certainly furnish a more healthy topic than the topics which otherwise tend to occupy the interest of young men in reaction from work. There can be no doubt that college athletics are beneficent in these respects, and that the elimination of the intercollegiate contests without the provision of an adequate substitute would be unfortunate and perhaps demoralizing to the morale of our colleges. But it is by no means certain that harmless substitutes may not be found.

Another nuisance of extremely deleterious sort whose benefits are conjectural is constituted by the yellow press. The magnitude of this evil is well understood by those who read the Baltimore, New York, Chicago, Boston or San Francisco papers, and it is probable that the press in some of the less important cities is as near the sodium line as is the worst journal in the cities mentioned. The power of the press to-day, especially of the yellow press, is enormous and far reaching. It has grasped the essential psychological principle of propaganda, namely, that opinions are best put over with the minimum of argument and the maximum of repetition. Countless illustrations could be drawn from recent occurrences. Perhaps the finest illustration is the repudiation of Burleson and of his administration of the Post Office, which apparently was brought about by extremely interested parties, working through the press, which, without giving any data or arguments, produced its popular effect by the continuously and flamboyantly reiterated assertation, both direct and by implication, that Burleson's administration was inefficient, in spite of solid facts to the contrary.

Another power which the yellow press possesses, and which it exercises frequently, is the power of ruining or very seriously injuring any private individual they please by printing scandal about him. Statements made concerning any individual, however good his previous reputation, and however lacking in foundation the statements may be, produce their effect. Even those readers who have good reason to know that no dependence can be put upon statements made in these papers, have, nevertheless, the tendency to believe what they read when conflicting facts are not actually presented. The effects of the stories printed are rather permanent, and are not removed even by successful damage suits against the papers.

On the credit side for this perhaps greatest nuisance of all, there seems to be little. I do not know at present what can be said in favor of the yellow press except that it is an unfortunate result of a principle of freedom which we can not afford to give up. No one

has as yet suggested any method of curbing the yellow press which does not involve worse consequences even than those of the yellow press itself.

In converse relation to the yellow press stands another nuisance which seems to offer no compensatory utility: a nuisance which has by no means reached its climax but is rapidly growing is the censorship of the movies, of books and of other vehicles of publicity. So far as any one can observe at present, the censorship of books has an effect diametrically opposite to that which is officially intended. If the publisher of a stupid book which is not selling, and which is a financial loss, can get the New York censor to suppress it, the financial success of that book is assured. I do not know how this game is played: whether through the gullibility of the censors, or whether through some other avenue of approach; but certainly, certain publishers seem to have the knack of working it most efficiently. Of course, really salacious books which are interesting enough to have a popular appeal do not need to resort to advertising of this kind. The popular Freudian books, for example, do quite nicely without it.

The same game has been worked with signal success by theater producers. Plays no worse than successful and much praised comedies, but which are too dull to attract the public, have been able to attain financial success by adroit manipulation of the demand for censorship, even where no censorship was actually possible. This game has been worked most profitably in New York and Baltimore this winter.

Obviously the greatest field for censorship is in the movies, and it is here that it is reaching its maximal expansion. Little actual effort is being made to censor the stage, perhaps because it is assumed that persons who can afford to pay several dollars for an evening's entertainment have no morals worth "protecting"; but the ten to fifty cent patrons of the movies are objects of great solicitude. The opportunities for manipulation are greatest here, and the chances that any Board of Censors might have any intelligence in matters pertaining to their censorship are rendered minimal by the method of appointment. The result, of course, is that perfectly harmless and, in fact, laudable types of production are prohibited; and the producers are driven to types of production which are much more vicious than the ones interdicted; the more vicious movies being usually passed by the Board of Censors. I could give a very long list of actual occurrences in this line, but the facts are too well known to any intelligent audience to need elaboration. So far, I do not know of any good results of censorship carried beyond that ordinarily exercised by public opinion, and by a minimum of police

inspection, which can be set over against the egregious evils which censorship entails.

Municipal pride is one of the nuisances whose foundations and motives it is most difficult to understand. Why should the dwellers in a particular city be so intensely anxious to have the city grow, and take such vast pride in its enlargement, in spite of the fact that the growth means increased taxes, increased discomforts of living and losses in many other respects? It is a fact, however, that citizens will gladly tax themselves excessively, and put up with needless deprivations and discomforts, in order to glory in a fifty thousand, or a hundred thousand, or two hundred thousand superfluous population.

On the other hand, certain advantages undoubtedly flow from municipal pride. In spite of its general misdirection, municipal pride has certain useful applications in that it leads to an improvement of living conditions: it is interested in clean streets, the reduction of crime, improvement of health, and so on. The case here is perhaps theoretically simpler than in the case of the other nuisances. What is really needed is a redirection of municipal pride away from merely numerical ideals towards qualitative ideals.

Another nuisance which offers some difficulty in its understanding is the wide-spread tendency towards amateur dramatics which has had its *floruit* not only in occasional organizations and in college dramatics, but more extensively in the "little theater" movement. The pernicious effects of amateur dramatics are of course obvious, if not on the personnel of the dramatic organizations themselves, at least on the long-suffering small audiences which are dragged in through college or family affiliations, or through social ties. The benefits of the amateur dramatic movements are perhaps hard to find, but there are probably utilities here also. These utilities consist not merely in the furnishing of occupation to certain individuals who can not easily engage in more useful or more highly cultural forms of activity—which is, of course, a social good, just as are the basket weaving and other therapeutic activities of various institutions—but consist also in the increased appreciation of good professional dramatics and in the higher standards in demands on the professional stage resulting from contrast with the amateur performances.

When we come to the consideration of the more direct interests of psychology, we find at least two nuisances which loom large, and which have caused much concern: nuisances which are in part inimical to the increase of knowledge, but also in part have deadly practical results. The first of these is Freudianism. Freudianism has undoubted ill effects in the obstruction of knowledge. Its funda-

mental theory of the "unconscious mind" is an opiate and substitute for inquiry, strictly comparable to the mythological nature-divinities of ancient peoples. Just as these ancient people explained thunder, lightning and other natural phenomena by saying "it is the work of the god," and were therefore satisfied without inquiry into natural causation, so the followers of psychoanalysis (and their numbers are now legion) say of this, that, and the other phenomenon that psychology is attempting to investigate, "it is the work of the unconscious mind," and think it has been explained by this phrase.

In many other directions, also, the Freudian movement has temporarily checked the research tendency, particularly with regard to dreams and the interpretation of symbols. On its practical side, it has been made the cloak of various forms of malpractice, including the extortion of large sums of money from dupes; and its social consequences are by no means negligible.

But on the other hand, the ultimate effect of Freudianism will undoubtedly be beneficial. The denial of the need of inquiry into the causation of mental phenomena is stimulating increased energy in that inquiry. There are indications that a renewed emphasis on the investigation of dreams and the psychology of symbolism will shortly be observable. As a matter of fact, the Freudian doctrine of symbolism was lifted bodily from the work of Payne, Knight and Thomas Inman and a score of other investigators of past generations. The Freudians have done little more than supply the *reductio ad absurdum* to doctrines which have long been in existence, and which have been too easily accepted. I doubt whether the impetus to an effective scientific study of the history and nature of symbols would have occurred within this generation, or perhaps within the next, without the stimulus of the Freudian absurdities. Furthermore (and this is by no means the least of the benefits derived from psychoanalysis), psychologists have been rudely shaken out of the complacent condition in which their fundamental theories and methods of interpretation were, to say the least, chaotic. The revival of scientific method in psychology and the shaking off of the chains of the naïve doctrine of "ideas" is, I believe, due in part to the general recognition that the main Freudian doctrines are after all but further, and logical, developments of the introspectionalists' principles and methods. The proper perspective upon behaviorism has also been attained in part through the study of its affiliations with Freudianism, and the recognition that, after all, that which has finally survived in behaviorism is nothing new, nothing antagonistic to psychology, but merely one of the methods which psychology has been using for many years.

The second nuisance which is of particular importance concerning psychology is a hydra-headed affair, which has frequently been characterized as fake psychology, which includes the various forms of "character analysis" and methods of "character development" or the "development of personality," and the application of these and similar nostrums to commercial and industrial fields. Here, again, the resulting evils are not merely the dissemination of fallacious theories, but include to a large extent practical results. Business men have been plucked as shamelessly as the traditional farmer was plucked by the lightning rod agent. Moreover (and perhaps this is the worst effect of all), the application of legitimate psychology to commerce and industry has been very seriously interfered with. In many cases the men who are victimized by the fake psychologists "see red" at the very name of psychology thereafter. In one instance, under my observation, the directors of a large manufacturing company were for some time averse to the employment by their engineering staff of a psychologist to work on an important practical problem, because this concern had a year or so before been victimized by a fake "psychologist"; and to the directors, all "psychologists" looked alike. I may add that in this case the engineers' plan was finally adopted, to the great financial advantage of the company.

Now, in spite of these serious evils resulting from the activity of the vast number of fake psychologists in the United States, there are undoubted benefits resulting from their mischief. In the first place, greater interest and greater energy on the part of the psychologists have been drawn to the problems of commercial and industrial applications. I doubt very much whether we would have the strong research movement in this direction at the present time were it not for the counter irritant the fake psychologists have applied to us. Furthermore, greater care and accuracy in work and statement, greater conservatism in conclusion have been imposed upon the psychologists through the necessity of setting up a distinction between real and fake psychology. The activities of the American Psychological Association in looking into the cases of individuals on its membership list who have adopted the methods of the faker have been brought about by the need of trying to keep our skirts clear. On the whole, the flood of quackery in this as in other fields of psychology is probably a good thing for psychology itself and for the serious and scientific psychologists.

# THE PHILIPPINES AS AN IDEAL SITE FOR A BIOLOGICAL STATION

By ALBERT W. C. T. HERRE, Ph.D.
THE PHILIPPINE BUREAU OF SCIENCE

THE lives and works of some biologists rise so far above the general average of accomplishment that they form in truth a series of beacons, illuminating the path of truth for those of us in whom the Promethean fire burns less brilliantly.

Perhaps the most notable quintet of the past generation was Darwin, Haeckel, Huxley, Wallace and Weismann, since the work of each was extraordinarily stimulating to human thought and activities in general, as well as to biology in particular.

It is a singular and most noteworthy fact that each of the above, as well as such a man as Humboldt, who achieved eminence in many diverse lines of scientific investigation, spent many years studying plants and animals in their native habitats in various parts of the world, but particularly in the tropics. Their studies of life in the tropics and the wealth of knowledge they gained from contact with the incredible richness of tropical faunas and floras gave them the solid foundation on which to rear temples of truth, instead of mere dreams and futile speculations. However much we may disagree to-day with any or all of those named, however much we may deem them to fall short of the truth as revealed to and by us, we must, nevertheless, admit that they were powerful and original thinkers, who based their theories and explanations upon a breadth of knowledge such as few of to-day possess. Again, we must say that this knowledge they gained primarily through life and study in the tropics.

With these and many other notable examples before them, it seems strange that so few biologists of the United States ever study in the tropics, even for a brief period. It is extraordinary that so few of them have no first-hand knowledge of the life so lavishly displayed in the greatest of all Nature's laboratories, the rainy tropics.

To argue for the value of marine biological stations is utterly superfluous, and many of our schools far inland make some sort of provision for training at one of the stations on either the Atlantic or Pacific coast. But none of our colleges or universities furnishes much opportunity for students to do either elementary or research work in the tropics, and as they practically never insist that their

embryonic research men must study in the land of perpetual summer, the tendency is for their biologists to become progressively narrower. The systematists (there are a few of those strange beings still extant) become more and more restricted in their range and are apt to look upon a field which Gray or Wood, Audubon or Baird studied long ago as the habitat of an unknown flora or fauna, and as a result to exclude from consideration other lands or even other parts of their own country. As for the workers in other fields proliferated from the natural history stolon so graphically limned by Professor Wheeler, they are sometimes in danger of forgetting that there is such a thing as outdoors at all, and tales of tropical life are to them but the faint penumbra of a once iridescent dream.

Let us rejoice that there are still a few bold and hardy spirits in the United States who venture far afield, even unto the tropics, although their studies and explorations are usually confined to the American tropics. As a matter of fact there are some Americans who have a worldwide field knowledge of their particular group, or a cosmopolitan understanding of the fauna or flora in which they are interested, but such biologists are few and far between, and are almost obscured by the mass of mental as well as physical stay-at-homes.

The botanical station in Jamaica, which should be thronged throughout the year, has attracted a few workers while the Guianan station so seductively portrayed by Beebe should be visited by ever-increasing numbers of biologists hungering for the strong meat so lavishly provided there. These and other stations already existent or yet to be created are vitally necessary if American biologists are to stand in the front rank, and must have adequate support.

But what about the old world tropics? What about the East Indian *Gebiet*, richest and most varied of all, everything considered? To what extent do our biologists appreciate the fact that under their own flag is a region unexcelled in richness and unsurpassed in the freshness and attractiveness of its biological problems?

For many years the Dutch have maintained their wonderful botanical station at Buitenzorg, and both botanists and zoologists have found there inspiration and fresh stores of knowledge. Just the other day the scientific press told us of the selection of Ké Island as a site for the new Danish tropical marine biological station. The European biologists are eager to travel half way round the world that they may enjoy the privilege of working in the wonderland hallowed by the explorations and studies of Beccari, Bleeker, Rumphius, Wallace and a host of other illustrious naturalists.

Just where do American biologists and American institutions figure in this and what effort is being made to emulate European

investigators? A few of our most eminent botanists and zoologists have travelled and studied in the East Indies, but not a single American college, university or museum maintains any kind of station in the Philippines, or even sends a single worker or student there to enlarge his experience and ripen his knowledge.

This, however, is not the whole story. It is bad enough that they do not support any sort of a laboratory in the Philippines, but apparently they do not want to do anything of the sort or even utilize the opportunities which have been offered them for almost nothing. Some time ago a letter was sent by Governor General Leonard Wood to the leading universities, museums and scientific organizations of the United States, offering the resources of the Bureau of Science in cooperation with them in various lines of study and research. With only a single exception all of them turned down the offer. One institution invested $250 to be used in collecting museum material; we have already sent them nine packing cases filled with specimens of corals, which cost them the large sum of $25. That money spent to maintain a fellow in the Bureau of Science for a year or to allot a traveling fellowship to the Philippines would repay incalculably the institution which did it seems impossible of comprehension by those who direct the affairs of educational and scientific institutions in the United States.

Perhaps it is in order to state briefly some of the features which make the Philippines an extraordinarily attractive field for the naturalist, whether he calls himself anthropologist, botanist, ethnologist, geographer, geologist, physiologist, zoologist or what not.

The Philippines, trivial specks as they may seem to the average American, in reality extend as far from north to south as from Canada to Mexico, with a breadth as great as from New York to Detroit. Of the nearly 7,100 islands and islets comprised in the archipelago, 466 are over one square mile in area, and about 400 are inhabited, while Luzon and Mindanao are each as large or nearly as large as Ohio. The land surface of the Philippines approximately equals that of the combined areas of the New England States and New York, and is almost as great as that of the British Isles, while the water surface comprised within the limits of the far-flung archipelago is 570,000 square miles.

Over this vast area of land and water, with its enormous and intricate coast line, it is self-evident that aquatic conditions, land and sea topography, can be by no means uniform. It is true that the whole region is in the tropics, but the great mountain ranges and the high sharp peaks scattered over the islands give an altitudinal range from half-submerged coral reef to a height of more than 9,500 feet. There is thus a great variety of climatic conditions

with all the diversity of plant and animal life which this makes possible, even though snow never falls and frost is unknown except to a few who live on the highest plateau of Northern Luzon.

Forty miles east of northern Mindanao is the greatest oceanic depth known, while the Celebes, Sulu and China Seas provide such an additional variety of life conditions that the marine fauna of the Philippines is richer than that of any other region in the world. To the Philippine shore line, which embraces every possible variety of coast, ocean currents carry aquatic life from far-distant parts of the Indian and Pacific oceans. Thus the fauna of the Red Sea, Zanzibar and the Marquesas is alike represented in the Philippines, while there is also a high percentage of endemic forms. There is not a single one of the larger islands which has been fully explored by naturalists or on which a single class of plants or phylum of animals has been thoroughly investigated. Anywhere in the islands one can, within a few miles of the coast or even of the largest cities, get into an entirely different environment which in many instances has never before been visited by a scientist or collector.

As a concrete example, in a few hours one can go from Manila into the mountains beyond Laguna de Bay and be in territory which is unknown to naturalists. Away to the northward it stretches for four hundred miles or more, a wild tangle of forested mountains, inhabited only by a few *remontados,* wandering Negritos, and two or three small and practically unknown pagan tribes. In other words, the whole northeast side of Luzon is a virgin wilderness, ripe for the scientific investigator.

Then there is the vast, half-explored island of Mindanao, so little known that as yet no trustworthy maps of it exist. At a height of 2,220 feet above the sea lies Lake Lanao, covering more than 110 square miles. Here, in a climate that makes mere existence a joy, is a rich harvest for the naturalist. For example, at one visit to Dansalan I obtained in the Moro market three new genera and a dozen new species of Cyprinidae. In the pathless mountain ranges and great forests which cover enormous areas in Mindanao one can study tropical organisms at all altitudes up to nearly ten thousand feet, dwell with tribes whose manner of living has hardly changed for a thousand years and observe the complex life of the jungle to his heart's content.

Just beyond Manila's front door, and but a few hours away, lies the large island of Mindoro, least known of all the Philippines. Right across from Batangas and very easily reached from Manila at any time of year is Puerto Galera, with its extraordinarily rich and varied "submarine gardens." Here would be an ideal spot for a marine biological station, for the coral reef swarms with an incredible variety and richness of animal life, including everything from protozoa to fishes.

Not only would students have an opportunity here to study a wealth of aquatic organisms such as no other region could surpass and but few equal, but not far away is the great peak known as Mount Halcon, rising to a height of over 8400 feet. This noble mountain, whose summit has been reached but once, offers in its jungles an amazing opportunity to both botanists and zoologists.

The best reason, however, for locating a marine laboratory at Puerto Galera, rather than at any one of a hundred other spots equally suitable, is its close proximity to the Bureau of Science at Manila. This brilliantly conceived institution has a large and very well-selected scientific library, especially rich in serial publications, which is not only unsurpassed in all of Asia and Malaysia, but is superior to that of most educational institutions in the United States. In addition the Bureau of Science is equipped with first-class chemical, physiological and pathological research laboratories. Beyond doubt arrangements could be made whereby the treasures of the Bureau Library could be utilized by marine station students, while those taking up problems in physiology, pathology, parasitology, tropical medicine or biological chemistry, to mention a few lines only, could make arrangements with the Bureau of Science which would be of great, indeed invaluable assistance to all concerned. By a system of working fellowships, some of the specialists in the Bureau of Science could devote part of their time to a marine station, giving it the benefit of their local knowledge and hard-earned field experience.

Should a marine biological station be established in the Philippines by some American institution or group of institutions it is certain that no European or American station could offer its workers such a wealth of material or such an opportunity for broadening their mental horizon. Those returning to the States after a period of work here would have a richness of background and experience such as could be obtained nowhere else in a like period of time. Their ability to interpret life, to correlate its various manifestations, and to help carry the light of knowledge a little further into the realm of ignorance and darkness would be enormously enhanced, not alone for the time being but for their whole existence.

The tropics possess the greatest resources and offer the greatest opportunities to man of any part of the globe. The day will come when these will be utilized to the full and the seat of civilization will again be changed to the regions it once occupied and where it naturally belongs. All lands are beautiful in one way or another, and all lands have their advantages. Yet the biologist has most to learn in the tropics, where life attains its greatest variety and luxuriance, and accordingly should establish there his training camps for those who are to be officers in the army enlisted against igno-

rance. And of all the world the Philippines offer the most ideal site for a marine biological laboratory.

In Philippine waters is perhaps the richest and most varied fish fauna in the world, probably a tenth of existing species occurring in the seas, lakes and rivers of the archipelago. Not only do we find there the unrivalled littoral fish life of the East Indies, as well as the wide-roving or cosmopolitan pelagic fishes, but to these are added forms which stray over from the coast of China or wander southward from Japan. So little known are the fishes of the Philippines that we never make a collecting trip without bringing in a new species, or something Rüppell discovered in the Red Sea nearly a century ago and which has not been collected since, or some fish hitherto known only from the South Sea islands.

When it comes to a knowledge of life histories, the food, breeding, migrations, diseases and other important matters concerning fishes, or their economic utilization and development, we have not even made a beginning.

At Puerto Galera, on the north shore of Mindoro, Professor Lawrence E. Griffin secured in a short time as many species of reef corals as, and only one genus less than, the Challenger Expedition secured in its voyage around the world. Several of these are new and still undescribed. Further collections in other parts of the Philippines would give an amount and variety of reef corals such as can be obtained nowhere else. Their collection and study would be a matter of great practical utility. Corals may make or destroy harbors and thus powerfully influence commerce and the life of countless thousands, while their fundamental connection with the geological formation of the Philippines in particular and with much of the world in general is sufficient of itself to show the value of their study.

Hugh Cuming, who returned to England in 1840 with the greatest collection of mollusks ever taken to Europe, spent four years in the Philippines, where he obtained his rarest treasures. Later collectors have shown that the Philippines possess the richest land molluscan fauna of any region of similar area in the world, but we know little more of their marine shells to-day than was made known by Cuming's collections. There is good reason to believe that the marine molluscan fauna of the Philippines is the richest in the world.

As long ago as 1907 Zahlbruckner urged me to go to the Philippines to collect lichens, saying it was the least known region in the world. Wainio's partly completed publications upon Philippine lichens demonstrate the extraordinary richness of the lichen flora of these islands, while my own fragmentary collections show that for the most part it is still very imperfectly known.

In 1900, perhaps 2,400 species of flowering plants and ferns were known from the Philippines. To-day the number already discovered is not far from 10,000. The remarkable botanical work carried on for the past twenty years by Director E. D. Merrill, of the Bureau of Science, who alone has described more new plants than are known from New England and New York, has added enormously not only to our knowledge of Philippine plants but also to the general affinities, history and distribution of Indo-Malayan plants. Yet giant pandans, huge forest trees and hosts of more or less conspicuous flowering plants are waiting still for the botanical explorer.

On a tree in my yard in Manila quantities of larvae were making queer cones out of the leaves on which they fed, and in which they remained during the chrysalis stage. Observation showed them to be something entirely new, yet zealous entomologists have been collecting insects in Manila for generations. Anywhere in the forest or fields one may find numbers of strange new species of insects.

The very valuable study of the vegetation of Mount Makiling, in which Dr. William H. Brown worked out the relation between the environment and physical types at different altitudes, is an illustration of an entirely different type of greatly needed scientific work. And so the story might be extended into all the divisions of botany and zoology, for the harvest is even greater for the workers in other lines than it is for the systematist.

Large areas of the islands have never been mapped, and there is much work yet for the explorer. There are tribes almost or quite unknown, and everywhere there is a rich harvest for the ethnologist and anthropologist. There is no other region where one can study leisurely and uninterruptedly a cross section of racial, tribal and family life extending without a break right through the centuries, from the twentieth back into medieval time, and then farther and farther away until finally the dim prehistoric period is reached when men lived in tree houses or no houses at all, neither planted nor harvested, and knew nothing of either textiles or cereals. If we study these people not merely with toleration but with sympathy we can obtain a remarkable insight into the daily life of our own ancestry in the not very remote days when they were rude savages on the banks of the Thames or roaming the gloomy forests of the Baltic. After all, there is no essential difference between the Northmen who horrified the rest of Europe by their piratical raids and the Moros whose marauding forays struck terror into the hearts of all their neighbors within a thousand miles or more. So, too, the Moro datu or Filipino cacique of to-day rules his taos in essen-

tially the same way that a "robber baron of the Rhine" or a Highland Chief held sway over the lives and fortunes of his people.

There is really but one serious drawback to life in the Philippines, if indeed it can be called one. I was brought up in the land of the mocking bird and the wood thrush, the scarlet tanager and the ruby throated humming bird, where birds of ravishing song or exquisite beauty were abundant. I know the joy of matching one's skill against the rush of the leaping black bass below Copperas Creek Dam, or of luring rainbow trout from the icy waters of a glacier-encompassed lake on Mt. Baker. But when one stands in the cool tropical forest at dawn and listens to the marvelous liquid notes of luscious melody gushing from the bird orchestra, or spends his days gloating over the riches of coral reefs, he comes to the point where he hates to leave it all and wishes to stay there forever. For the naturalist the tropics do not mean *dolce far niente;* rather they fill him with inspiration and zeal to work constantly to the limit of his ability.

Of course some people fear the tropics because, forsooth, the sun shines or because of old superstitions and traditions which had their origin among the cold and foggy northlands of Europe and were due primarily to ignorance, prejudice and conceit. Our ideas on the subject were imbibed from European sources, principally English, all dating back naturally to the days when nothing was known of hygiene, sanitation, infection, the relation of insects to disease and the importance of intestinal parasites. The blunt truth is that in spite of all that has been said and written on the subject, as yet we know almost nothing about the effects of tropical climates upon people in general and the north European stock in particular. One author has written a book upon the baneful effects of sunlight upon northern white people, but has utterly ignored all the factors which so commonly slow down or incapacitate the people of the tropics. Yet, as a matter of fact, here in the Philippines the sunlight is not so intense nor for so many hours daily or yearly as it is over a vast area in the arid southwest and western parts of the United States. Neither is the heat so great here in the tropics as it is over most of the United States during a considerable part of the year. The Imperial and Salt River Valleys, the Sacramento-San Joaquin basin, the plains of Nevada or West Texas, the great corn belt, or the Yazoo cotton fields can all show months of temperatures far in excess of anything ever seen in the Philippines, while in the Mississippi Valley and Gulf states the heat is as great at night as in the daytime, so that suffering, sweltering humanity can get no rest. Here in the Philippines, where sunstroke is unknown, surely the climate is not more dangerous than that to which millions in the United States are already accustomed.

Even were the picture as black as it has been painted, should that deter the modern field scientist any more than it did the naturalists in days of yore? Beccari and Wallace both plunged into the East Indian jungles when nothing was known of the causes of diseases or how to avoid successfully malaria and other infections, yet they both lived to a very advanced age.

It is axiomatic that until we eliminate intestinal and other parasites, which in some places infest an enormous percentage of the people, and likewise overcome the effects of an impoverished diet, defective in variety and quantity, resulting in malnutrition or semi-starvation or both, we can know nothing of the results due to a tropical climate. It has been the mode to impute the lack of physical strength and the lack of energy of many people native to the tropics to the ill effects of the climate, when as a matter of fact they have been weakened by hook worm, malaria, filariasis, amoebic dysentery and other infestations and infections. It is, moreover, quite true that the greater number of those who fall victim to such diseases do so as a result of their wilful neglect of perfectly simple precautionary measures. Especially is this true of many Europeans and Americans, who deem themselves of superior clay to natives of the tropics.

Wherever we find native workmen sufficiently well fed and leading an active life we find them well muscled, capable of great exertion and able to do efficient work. One could not ask for better specimens physically than the longshoremen and sailors of the Philippine ports, or the lean hard Samals who not so long ago were the most dreaded of pirates. On the other hand, many of the tao and illustrado classes alike are miserably puny specimens, equally deficient in muscle and vitality. But this is due to many causes, some of them already cited, others having to do with social traditions and customs, but none traceable to climate.

Ever since white men began to make slaves of or to control the natives of warm countries, they have said, in order to bolster their position, that white men could not endure any form of manual labor in the tropics. Not only have our soldiers performed herculean labors in the regular performance of their duties, but the many American ranchers scattered all over the Philippines, often compelled to turn their hands to every form of the most arduous and exacting manual labor in their struggle against odds to subdue the wilderness and create productive estates, have shown that so far as physical welfare is concerned white men can do anything in the tropics that they can do in the United States and still maintain exuberant health.

In this connection it is well to observe that the eminent English authorities on tropical medicine, Castellani and Chalmers, state

that the most potent disability factor in the tropics is alcohol! Yet English tradition, sedulously cultivated by many Americans, has it that "You must drink lots of whisky and soda to keep in health in the tropics."

It requires slight observation to show that the natives of the tropics vary as do all people, and that a large percentage of the brown or yellow skinned people do not stand heat so well as do many white people. Any person who is in first-class physical condition can live in greater comfort and with less ill health in the tropics than he possibly can in Chicago, New York or Boston. If one eats plenty of wholesome food, using freely fresh native fruits and vegetables, takes plenty of exercise, takes the same precautions against typhoid and other infections that he would in most parts of the United States and lets alcohol alone, he will find his store of vitality not only maintained but augmented, and the human motor will neither freeze nor overheat but will be able to work with its maximum efficiency.

In conclusion, let us state the following propositions:

(*a*) The tropics are Nature's most wonderful laboratories.

(*b*) The biologist can learn more in the tropics than in any other part of the world in a like period.

(*c*) The Philippines have the richest aquatic life known.

(*d*) The Philippines are less known scientifically than any region of like area.

(*e*) A marine biological station should be maintained in the Philippines by a group of American institutions.

(*f*) Such an institution would have many advantages, not the least of which would be the opportunity for cooperation with the Bureau of Science.

(*g*) Such an institution would be a great factor in freeing American biologists of provincialism and ingrowing narrowness.

(*h*) It would have a tremendous influence upon the development of American biology and would give it added prestige.

(*i*) Properly conducted, a scholarship at the Philippine marine biological station would be considered the highest honor that a young biologist could attain.

(*j*) The college professor or foundation or museum worker would find that six months or a year in the Philippines would not merely rejuvenate his old ideas but would give him invaluable new points of contact.

Lastly, let us all take hold and make such a vision a beneficent reality.

# INACCURACIES IN THE MATHEMATICAL LITERATURE

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SINCE the beginning of the history of science there have been some men who degraded their contemporaries in the eyes of future generations by recording their own ignorance. Many of those who have had the writing itch have been neither the best informed nor the most accurate observers of their own generation. The term "mathematical accuracy" is frequently used to denote ideal accuracy, and one of the most important elements in a mathematical training is the cultivation of such accuracy. The professional mathematician is compelled to employ a method of exposition which is naturally avoided as far as possible by other scientists, *viz.*, the method of basing many of his arguments upon results which can be derived from the postulates only by means of a long process of reasoning. His remoteness from these postulates makes it necessary to place full confidence in this long process of reasoning, for weakness therein would imply not only the danger of falling but also the danger of falling from such a great height that the fall would likely be fatal.

The great remoteness of much of the mathematical developments from the postulates on which they are based implies the safety of the intervening structure, and the fact that this structure could easily be made so safe, in turn, implies the tendency to venture so far away from the postulates in this particular field. A mathematician's thought can not be centered continually on his purely mathematical developments. He, too, has an interest in topics which do not yet admit of mathematical treatment. He, too, must deal largely with questions where it is not safe to venture far from the postulates and where it is not customary even to formulate these postulates explicitly. It is here where his mathematical training may become a handicap unless he distinguishes carefully between questions which admit and those which do not admit mathematical treatment.

A lack of such discrimination was noticed by Napoleon in P. S. Laplace, whom he appointed as minister of the interior but had to dismiss about six weeks later as a misfit for this position. As

Napoleon maintained that the advancement and perfection of mathematics were intimately connected with the prosperity of the state, and was unusually interested in mathematics for a man so deeply involved in politics, it is instructive to note his observations relating to the noted mathematician in question, which were as follows: Laplace failed to seize a question from the true point of view; he sought subtleties everywhere, having only problematic ideas, and he carried the spirit of the infinitely small into the administration.

During the last half century a rapidly growing number of mathematicians have become interested in the early history of our subject. This has become necessary in order to avoid duplication, and to secure greater unity and a clearer insight into the fundamental tendencies of the rapid advances made during this period. Even in this field the mathematician soon discovered that he could not always proceed with the degree of certainty which characterized his work in pure mathematics. Not only are many questions of fundamental importance relating to the early developments of mathematics involved in contradictory records and in records which are entirely unreliable, having been made by people who had not yet acquired the art of accurate observation, but even many of the more modern historical questions have such extensive ramifications that it is extremely difficult to make brief and fundamental statements about them without the danger of conveying incorrect impressions.

The human race seems to have always permitted a considerable digression from the truth for the sake of producing certain effects supposed to be wholesome. Inaccessible and unexplored regions have been allowed to furnish the imagination much food, which frequently served to awaken thoughts of a more or less serious type. In nature these regions have become more restricted, and in the thought world the extensive scientific literature has equally contributed towards substituting realities for vague imaginations as objects of thought. It seemed to me that the history of mathematics should not be allowed to lag behind in this slow but sure progress towards reality, for the truth is to make us free. Moreover, it seems that the university instructor should try to help those teachers who have had less opportunity to use good libraries.

Historical fiction has probably never been relatively less popular than it is in our days. Just as many pulpit orators of our times express their indifference as regards the literal accuracy of historical statements which seem to be fraught with spiritual significance, so many of our teachers are practically indifferent as regards the authenticity of such interesting legends as the sacrifice of a hecatomb by Pythagoras or the solution by the young Des-

cartes of a difficult challenge problem which is said to have attracted the attention of the public in Breda, Holland. Even such an authoritative work as the eleventh edition of the *Britannica* refers, under the name of Descartes, to the latter as if it were a well-established historical fact. The growing popularity of mathematical history has afforded an unusually large number of temptations for presenting fiction in place of established facts in case the latter were not known to the speaker or writer.

Few would probably be inclined to defend statements which are evidently incorrect. For instance, if one reads in a history that J. Ch. Burckhardt died in 1815 and notes in the following line that he published a factor table in Paris in 1817, one is willing to admit that at least one of these dates should be changed. Men are not known to have published mathematical tables after they were dead, even in such a mathematical center as Paris. Similarly, when one reads that De Moivre extended "the theorems on the multiplication and division of sectors from the circle to the hyperbola," one is willing to admit that historical statements should mean something, notwithstanding the fact that a statement similar to this appears on page 200 of volume 7, Marie, "Histoire des Sciences Mathématiques." As an instance of evident inaccuracies of much larger historical significance we may refer to the following statements: "It is to be observed that in Diophantus, and in fact in all writings of antiquity, the concept of *quotient* is wanting. An operation of *division* is nowhere exhibited. When one number had to be divided by another, the answer was reached by repeated subtraction."

Just as the term division has two distinct meanings in elementary mathematics so the term quotient has two distinct meanings. When the remainder is zero these two meanings practically coincide, and it seems reasonable to assume that this special case was first considered. The early appearance of fractions in the Babylonian and the Egyptian mathematical literature points to the very early use of division as the inverse of multiplication, but one concept of quotient is independent of this use. It is, therefore, very far from the truth to say that concept of quotient is wanting in all writings of antiquity and that the operation of division is nowhere exhibited. A quotient obtained by repeated subtraction is just as much a quotient as if it had been found by the inverse of multiplication, but even if the latter were the only meaning of quotient the quotation under consideration would evidently be misleading.

A historical statement frequently met in the accounts of the work of Galileo is as follows: "Up to his time it was believed that a cannon-ball moved forward at first in a straight line and then

suddenly fell vertically to the ground." That this belief was not universal up to the time of Galileo results from the fact that Tartagila, in his *Nuova Scienza*, 1537, contended that the path of a projectile is curved in every part. This quotation seems to me to be a great reproach on early human thoughtfulness, for what boy has not noticed the paths of stones thrown by himself or his playmates. We owe it to the respectability of our forefathers to modify such statements as far as possible in harmony with historical evidence. The glorification of a few at the expense of the rest of mankind is neither sane nor democratic.[1]

The accuracy in mathematical history which is under consideration relates however mainly to a different line of thought. What we have in mind is the most effective degree of accuracy. The question may be raised whether the accuracy to which the pure mathematician is accustomed should characterize his work in mathematical history or whether he should allow himself here greater freedom as regards the use of statements which are only approximately true. A partial answer to this question is perhaps furnished by the fact that a mathematical history should be constructed with a definite view to the needs of the readers for whom it is intended, and that we should have not only one type of such histories, but various types so as to reach most effectively a large body of readers. Some readers would appreciate the precise statement that "a necessary and sufficient condition that a regular polygon of $n$ sides can be constructed by means of ruler and compass is that the order of the group of isomorphisms of the cyclic group of order $n$ is a power of 2," while to others this statement would be meaningless.

In each type of histories every statement should be clear and definite and the explanations should be as complete as the available space permits. It may be desirable to make many historical assertions which can not be definitely proved, but these assertions should be in the nature of hypotheses which are in accord with all known facts and which are supported by a large number of facts which might otherwise appear unrelated. For instance, the assertion that the ancient Greeks did not use negative numbers can clearly not be proved definitely, but it is commonly accepted as a legitimate statement. On the other hand, the assertion is frequently made that the ancient Greeks considered only one root of an algebraic equation even when such an equation has more than one positive root. This is a more questionable assertion since Archimedes considered the condition under which a certain cubic equa-

[1] F. Cajori, "A History of Mathematics," 1919, pp. 172, 229, 440. See also "A History of Elementary Mathematics" by the same author, page 37 of both editions.

tion has more than one real root.[2] This is, however, an exceptional case in the Greek literature that has been preserved.

Many of the leading mathematicians have made broad historical statements which are very useful even if it is impossible to prove them. Among these is the following remark made by G. Darboux, "Oeuvres de Henri Poincaré," volume 2, page xxiv: "Among all the discoveries which the mathematicians have made in the course of the nineteenth century, the most fertile without doubt is that which is due to Cauchy relative to Taylor's series and to the conditions of its convergence. One may say that it has renewed all branches of analysis." As the nineteenth century is so rich in fundamental mathematical discoveries it might appear bold to pick out one and to ascribe to it such a preeminent position as is here done. On the other hand, it is scarcely possible to lay too much stress on the importance of the particular discovery in question, and such statements, emanating from high authority, are read with great interest and profit even by those who would not be willing to endorse them unreservedly. Some statements are very useful, even if they are not true as regards all details.

As another instance of a broad historic statement by one who was not a professional mathematical historian we may quote the following due to S. Lie: "While the curve as the representation of a function of a single variable has been the most important object of mathematical investigation for nearly two centuries from Descartes, while, on the other hand, the concept of transformation first appeared in this century (the nineteenth) as an expedient in the study of curves and surfaces, there has gradually developed in the last decades a general theory of transformations whose elements are represented by the transformation itself, while the series of transformations, in particular the transformation groups, constitute the object."

It is desirable to distinguish between mathematical history and mathematical archeology. The mathematical historian must understand broad fields of mathematics and must be able to discern the broad tendencies as well as some of the main details. On the other hand, the mathematical archeologist needs to know but little mathematics and may properly limit himself to details which are of comparatively little interest to the mathematical historian. A collection of old MSS. and of old arithmetics or of old pictures of men about whose physical features we know nothing is more suited for the laboratory of the archeologist than for the study of the historian, although the latter is sometimes in need of the results ob-

[2] *Cf.* T. L. Heath, "The Works of Archimedes," 1897, CXXVII; F. Cajori, "A History of Mathematics," 1919, p. 61.

tained by the former and will naturally be greatly aided by an understanding of some of the details relating to the work of the former, but it is unfortunate that this work is so widely confused with true mathematical history.

We stated above that Napoleon dismissed Laplace from the position of minister of the interior at the end of about six weeks. Those who are familiar with Netto's account of the affairs in Volume 4 of Cantor's "Vorlesunger über Geschichte der Mathematik," page 228, may recall that it is here stated that Laplace was dismissed after six *months,* and that the same error appears on page 260 of the second edition of Cajori's "History of Mathematics." At the latter place it is also incorrectly stated that Napoleon was made emperor on the 18th of Brumaire, referring to the notable day in French history when Napoleon practically seized the reins of the government in 1799. He was, however, not made emperor until 1804. It seemed desirable to refer to these details, since otherwise some might be led to believe that the statement made above was due to an oversight. It may be added that the term "divergent series" was not used by James Gregory as stated on page 228 of the latter work and that the figure which appears on page 326 thereof does not relate to Bolzmann's "H-curve" as there stated but to the well-known curve described by Koch. Moreover, the assumption that "in any circle the inscribed equilateral quadrangle is greater than any one of the segments which lie outside it" can obviously not be regarded as a simpler and more obvious axiom than the parallel axiom, as stated on page 302.

Accuracy in mathematical history implies an exhibition of the central thoughts in their true relations and hence it implies mathematical insight of the highest order. The greatest mathematicians have also been the greatest mathematical historians in the sense that they first exhibited the fundamental relations in the proper light. One follows the thoughts of such men with a growing insight because of their accuracy. Such accuracy is of much greater importance than the accuracy relating to details, such as exact dates or exact references. In particular, one seldom reads an *aperçu historique* in the "Encyclopédie des Sciences Mathématiques" without feeling inspired by the clarity resulting from the accurate formulation of fundamental thoughts. This type of accuracy is of the greatest importance in mathematical history because the trains of thoughts awakened thereby connect many hitherto distant facts and present one of the feasts of harmonizing thinking, so much prized by those accustomed to mathematical meditation. That even eminent mathematicians are not always en-

tirely successful in this direction may be seen from Klein's criticisms of his own noted Erlangen Program.[3]

A serious handicap in the development of a reliable general history of mathematics has been the fact that the earlier parts of such a history are largely based on mathematical archeology, and this subject is comparatively young. It is mainly due to this fact that our general histories of mathematics have so soon become out of date. Even the history of Montucla and the history of Cantor were soon pronounced behind the times, and one consults these works now with the understanding that much that is contained therein must be modified in view of later discoveries. Great impulses for the study of mathematical archeology were furnished about the beginning of the nineteenth century by the discovery of the famous Rosetta stone, the deciphering of cuneiform inscriptions, and the appearance in Europe of a Sanskrit grammar. The later discoveries in regard to the Maya of southern Mexico have led to some striking results relating to the arithmetic of the aborigines of America.

The general subject of accuracy in mathematical history seems to have been endorsed by the American Mathematical Society in view of the fact that the older official journal of this society is called a "historical and critical review." This is a somewhat bold position to take, since a really critical review often contains statements which are disagreeable to the author. In the oldest German mathematical periodical which survived, the editor explicitly stated in the preface of volume 2 that everything which could hurt any one was unconditionally and strictly excluded. It is interesting to note that the American Mathematical Society, at least in theory, assumed a bolder attitude. The explicit association of the terms historical and critical should be noted. While neither of these terms implies the other, the literature described by one is apt to have an element to which the other applies.

There is a very wide difference between directing attention to inaccuracies in a book and expressing an unfavorable opinion of it. There are comparatively few books which do not involve known inaccuracies and some of the best ones contain more inaccurate statements than others which are much inferior but whose authors were skilful in hiding their own ignorance. Moreover, all agree that serious inaccuracies should be corrected and that an open and frank discussion of such inaccuracies is often very instructive. We are glad to forgive such sins, but we would like to know something about the sins which we forgive. There are also many questions

[3] Felix Klein, "Gesammelte Mathematische Abhandlungen," Vol. 1 (1921), p. 414.

where differences of views exist and it seems undesirable to try to make all agree as to details. Intellectual combats are at least as wholesome and as invigorating for youths as the physical ones and their existence is only a sign of normal life. Even the most stalwart members of the church sing with great enthusiasm "Onward Christian Soldier," and those who shriek when they see a mouse often adore the man in a soldier's uniform.

The approximately fifty thousand mathematical books and pamphlets which have been published may be regarded as so many largely helpless children. They can, however, not mend their own ways like other children can. Most of their authors are dead, and those who are still alive in many cases claim that they could do much better if they had another chance. These books reflect shortcomings which many of their authors outgrew but which they themselves can never outgrow. While they may, therefore, excite our pity and incite us to do our best to make their faults harmless they constitute nevertheless our greatest time-binding heritage.

Although their authors may continue to have paternal interest in them long after their publication, they themselves begin to exert public influence from the time of their publication and it becomes then the duty of the public to see to it that this influence is wholesome. This is usually done by means of reviews which direct attention to their merits, if they have any, and warn those who seem to be in danger of being misled by possible demerits.

The reviewer of a book becomes a kind of father-in-law thereof, willingly or unwillingly as the case may be. In either case he is apt to learn much more about the book after preparing the review than before. He may even find it desirable to try to modify the impression which his review conveyed to the public, especially if the book is of such a nature that a considerable portion of the public reached by it is not in position to discover easily the needed modifications, as is likely to be the case in a historical work.

Mathematical history reveals certain invariants in human thinking which are of great interest in the study of the intellectual development of the human race. Some of these invariants were formulated by the Greeks and were called "common notions" in Euclid's "Elements." Long before such a formulation one notices invariants in mathematical thinking. For instance, in measuring it was always recognized that areas, such as those of rectangles and triangles, should be measured by square units having a linear unit for a side, and that volumes, such as those of prisms and pyramids, should be measured by cubical units having a linear unit for an edge and therefore square units for their faces. Even the work of Ahmes and the writings of the early Babylonians give evidences

of the use of such units, and later writers proceeded similarly. It is true that there are also instances of units of surface which are not squares such as our acre, which is a rectangle whose sides are 22 yards and 220 yards, respectively, and the Chinese unit rectangle whose sides are 1 and 6 tchis, respectively, but in these cases square units are also used. Such units constitute clearly the simplest of conventions since they give rise to easy rules, and we have here evidence of the influence convenience has exercised in the development of our subject.

These evidences of the invariance of human thinking raise the question whether the human mind has improved as regards mathematical thinking during historical ages. The crude mathematical thinking displayed by some modern writers when referring to mathematical subjects seems to furnish little evidence of general improvement. It is true that there is more accurate mathematical thinking now than there ever was before, but this difference seems to be more largely due to training than to native ability. Mathematical capacity grows by use, and the opportunities for this use have always existed. There are still many who would readily accept the statement that the perimeters of similar fields vary as their areas, and the inaccuracy of the mathematical thinking of a Gerbert, later Pope Sylvester II, has been equalled by some mathematical historians who dealt with his works and gave him too much credit, especially for his letter to Adelbold.[4] The main historical significance of this letter is that it exhibits the great mathematical weakness of the Romans, and of Gerbert in particular, near the end of the tenth century, but references thereto found in several of the most popular general histories of our subject give a very different impression.

Those who are inclined to believe in the mathematical superiority of the modern human intellect are confronted with one serious obstacle by the history of our subject, *viz.*, the work of the Greeks. If the work of the Greeks and that due to its influence could be removed from the mathematical history of ancient and medieval times this history would apparently be reduced more than 90 per cent., and would be almost confined to practical methods of calculation and measurement. The astounding monuments created by the works of Archimedes, Apollonius and Euclid are not excelled by those due to the work of modern intellects if we make allowance for the higher ground upon which the latter stood. While we cordially grant to the Greeks the most prominent position in ancient

[4] See *School Science and Mathematics*, Vol. 21 (1921), p. 649. A discreditable feature of this letter is that it aims to replace a fairly accurate method of approximation by one which is much less accurate.

mathematical history we are keenly aware of the fact that their early work makes it difficult to support the theory that elegant results in pure mathematics are appreciated by all future generations. In fact, it is probable that comparatively few of the Greeks understood the work of their mathematical giants. The later mathematical retrogression may have been largely due to the fact that real mathematical attainments among the Greeks were too isolated.

One might at first be inclined to conclude that the numerous errors which appear in some of our popular general histories of mathematics and were carried over into new editions of these histories are evidence of a lack of a keen appreciation of our subject on the part of the modern reader. Keen appreciation implies that our thoughts dwell on a subject until the connections with others become clear, and error is apt to exhibit itself during this process. Unfortunately, few of those to whom these errors have thus exhibited themselves found it convenient to make their knowledge along this line useful to others, since they were more deeply interested in other phases of our subject where they could render needed service. As long as the general histories of our subject were read by comparatively few this course was perhaps natural, but with the increase in the number of readers in this field there comes also an increased need of service along the line of accuracy.

It is a singular fact that notwithstanding the great difficulties inherent to the history of our subject nearly every teacher of mathematics thinks that he can teach this history. Many are those whose mathematical knowledge is very inferior and yet they offer courses in the history of our subject. Frequently such courses are largely devoted to mathematical archeology. Several years ago Enestrom noted that the secondary teachers of Sweden were not prepared to give reliable historical information in connection with their mathematical courses and hence they were properly not advised to furnish such information for the purpose of making their courses more attractive. Is it not time to warn the American teachers of secondary mathematics that they too are in danger of doing more harm than good by trying to impart historical information which they are in no position to verify as regards accuracy? The references to inaccuracies noted above may perhaps serve to initiate such a warning in our land.

The need of this warning might be illustrated by statements found in some of our best textbooks. In particular, the second paragraph of the introduction of such a work[5] begins with the following sentence: "Algebra, on the other hand, was unknown to the

[5] Osgood and Graustein, "Plane and Solid Analytic Geometry," 1921.

Greeks." If one consults the "History of Greek Mathematics" by Sir Thomas Heath, which appeared during the same year as the textbook in question, one finds that practically all of Chapter 20 is devoted to Greek algebra, and that some earlier pages are devoted to the geometrical algebra of the Greeks. It is true that it would be possible to define algebra in such a way as to exclude the work of the Greeks from this subject, but this is not commonly done, and hence the quotation noted above is likely to mislead the student. In fact, it is followed in the same textbook by the equally misleading statement that the beginnings of algebra are found among the Hindus. H. Hankel expressed a somewhat similar view, but Paul Tannery and others have pointed out that Hankel gave undue mathematical credit to the Hindus.[6]

The work of the mathematical historian is made more difficult by the frequent use of the same term with different meanings. Even such a commonly used term as "Euclidean geometry" has at least three different meanings in modern mathematical works of reference. In some of these the term is used with the meaning attached to it by Gauss, *viz.*, as any geometry in which the parallel postulate is assumed, while others use it as the geometry of the invariants under the group of transformations under which the distances between every pair of points is an absolute invariant. This is done, for instance, in the French mathematical encyclopedia, Tome 3, Volume 1, page 344. On the other hand, in such a reliable work of reference as the second edition of Pascal's "Repertorium der höheren Mathematik," Volume 2, page 61, the term "Euclidean geometry" is used for the geometry of the invariants under the principal group of geometry which includes also the similarity transformations and hence does not leave distances unaltered. The angles are, however, absolute invariants under this group.

Mathematical inaccuracy is closely related to mathematical indefiniteness. Such indefiniteness may confront the mathematical student very early in his career. For instance, in some elementary algebras he is told (properly according to my view) that such a relation as $9 - 7 = 2$ is an equation, while in others he finds the assertion that an equation must always involve a symbol to which we can assign a value and thus arrive at an identity. In some textbooks he is told that a determinant is a certain polynomial, while in others he finds that what is commonly known as the matrix of a determinant is the determinant and that it *represents* a poly-

[6] Paul Tannery, "La géométrie grecque," 1887, p. 6. See also three lists of marginal notes on the second edition of Cajori's "History of Mathematics," published in *School Science and Mathematics*, Vol. 19, p. 830; Vol. 20, p. 300; Vol. 23, p. 138; *Cf.*, *School and Society*, Vol. 16 (1922), p. 449.

nomial. Professor Bôcher criticized Kowalewski in the *Bulletin of the American Mathematical Society, Volume* 17 (1910), page 139, for using the word determinant frequently in the sense of matrix, adding that "this error is so sanctioned by universal usage that it must, for the present, be regarded rather as a defect of the age than of the individual." On the other hand Bôcher himself speaks of the rows and columns of a determinant within two pages after defining it as a polynomial. It is possible but not customary, as I understand it, to associate rows and columns with a polynomial regarded either abstractly as a function or concretely as the algebraic sum of monomials. It may be that the defect of the age is that we do not have a satisfactory accepted definition of the term determinant. This term need not be restricted to a polynomial alone nor to a matrix alone but it may represent a combination of the two. From this point of view a determinant does not represent a polynomial but the matrix of the determinant represents this polynomial. Similarly, the polynomial implies a square matrix if it is regarded as the polynomial of a determinant.

The author of the present paper does not feel certain that all contradictions should be eliminated from the mathematical literature, but he feels quite certain that the student should be informed as regards the existence of contradictions. This has not always been done. The history of the Archimedian postulate proves that at least since the time of the ancient Greeks mathematical treatments have sometimes been made easier by denying the existence of what seems evident but may be denied without getting us into practical difficulties, as is done in assuming that all right angles are equal. The fact that contradictory definitions of such common terms as equations, determinants and circles have persisted without causing much embarrassment tends also to support the view that mathematical progress may have been aided by the existence of some contradictions in its literature. Even the mathematician may gain by construing words to fit their surroundings instead of regarding them as being independent of their positions. In fact, he should frequently read the truth into false statements, but he can scarcely be expected to overlook the fact that the statements are actually false. For instance, when one reads in Netto's "Gruppen und Substitutionentheorie," 1908, page 147, that every regular transitive group is imprimitive one sees easily that the group of prime order is to be excepted, but one should not be expected to regard the statement as correct.

The author of the present paper has perhaps been unusually credulous. At any rate, he has been led into many a mathematical trouble by relying upon the accuracy of statements found in works

of good reputation which he found afterwards to require modifications of various degrees. He has been led to feel that his path would have been easier if he had been warned, especially as regards the unreliability of many commonly accepted statements relating to the history of mathematics. Perhaps there are others who will profit by such a course. Hence the present note of warning. In view of the fact that the mathematical literature is probably more accurate than that of any other large subject our intellectual road is beset with comparatively few of such pitfalls as we have here and elsewhere aimed to mark by red lights. The few so-called replies which have appeared do not seem to prove that any of these lights mark a clear road.

# CONSERVATISM AND RADICALISM—SOME DEFINITIONS AND DISTINCTIONS

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MANY years ago, Walter Bagehot[1] showed how necessary it is for every social group to acquire what he called a shell of custom—some form and organization of authority to hold the group together in physical and spiritual solidarity and to curb the self-will of individuals who might endanger the cooperative cohesion and defensive powers of the group. But, as Bagehot goes on to suggest, once this shell of custom has set, it has sooner or later to be smashed, else it will stifle the growth and strangle the intellectual and moral evolution of the very society it was designed to serve. As a rule, when the provocation has become sufficiently great, men have risen who have not been lacking in the necessary courage and strength of character to undertake the task. Always, indeed, there have been would-be shell-smashers, men who rebelled inwardly or outwardly, and frequently with violence, against the particular controls and institutions imposed by historical accretion, by the passive, non-resistant indifference of the phlegmatic or repressed masses and by the special interests of powerful individuals or classes.

Thus sponsors of things-as-they-are and advocates of change, modification and transformation are always set over against one another in an attitudinal and active conflict, the intensity of which depends both upon the psychological temperament and character of the two groups, conservative and radical, respectively, and upon the degree of divergence or opposition of their respective interests.

The scale of attitudes which different men and women take toward social change may be compared to the solar spectrum. At the opposite ends stand extreme radicalism and uncompromising reaction. Between these extremes are conservatism and liberalism, or progressivism, each with its various degrees of intensity and its shading into the adjacent attitudes. Thus the attitudinal spectrum reads, from left to right, radicalism, liberalism or progressivism, conservatism, reactionism. Like the colors in the solar spectrum these attitudes grade each into the next so gradually that it is impossible to draw a sharp line between any continuous two.

[1] "Physics and Politics," 1873, Ch. 1.

Conservatism, generally speaking, is simply that system of sentiments, that mental attitude, which causes the individual to accept with equanimity and approval things-as-they-are (or would be if liberals and radicals would only let them alone), which desires little if any change, and which opposes with vigor any proposal for radical transformation. In its purest form conservatism regards whatever is as right and final. The typical conservative opposes not so much relatively innocuous temporizing and tinkering with unimportant social details, and not so much the evolutionary drift which may mean in the long run very significant transformations, of which he is ordinarily oblivious, as he does thorough-going and consciously conceived and directed reform or revolution having to do with the more fundamental aspects of thought, economic organization, and social relations. Conservatism, if it could have its way, would thus stand still, maintaining social relations and processes, thought, belief and culture practically as they happen to be at the time, and resisting, on the one hand, the innovations of progressive and radical, and on the other, with perhaps a little less enthusiasm, the reversionary ideals of the reactionary.

With reactionism the conservative is not in accord, because reactionism would return to some previously current but now abandoned mode of thought and system of organization. The reversion advocated by the reactionary is distasteful to the conservative since it would mean a change in relations and activities which would interfere with his habituation and attachment to things-as-they-are. Nevertheless, the thorough conservative is more nearly related to the reactionary than to the radical. Conservatism is opposed to radical thought and action, and is antipathetic to liberalism, because the conservative not only is averse to change of any significant kind, but has a lively fear of the new and unfamiliar. Both the introduction of new and unfamiliar arrangements and a return to some previously existing order involve change, and hence more or less disturbance of established habits and points of view. Both entail discomfort to the conservative, therefore, but the proposals of the reactionary are likely to seem less subversive than those of the radical, although as a matter of fact they may be quite as much so. The conservative does not want the existing shell of custom smashed or even appreciably bent, but if its form is to be modified at all he would rather go with the reactionary back to the tried and familiar than with the radical and his innovations.

Progressivism stands midway between conservatism and radicalism and partakes of the milder characteristics of both. The progressive welcomes and works for orderly and gradual changes which can be brought about by planned endeavor and the conscious

direction of social evolution. He is not so deeply habituated to things-as-they-are as is the conservative nor characterized by the irrational fear of change which marks so many timid temperaments. But progressivism is not devoid of fear. It fears the disruptiveness and discontinuity of radicalism. Where the radical would smash the existing shell and substitute another, the progressive would rebuild the existing shell piecemeal, and in this process of gradual reconstruction remodel its form and content.

The progressive holds, in other words, that however rapidly human advance may be accelerated by innovative initiative and rational direction, it must nevertheless be evolutionary and continuous. The future must grow out of the present, as the present has come from the past, by a "natural," orderly process of development, not through those sudden jumps and changes of direction, those "discontinuous variations," to borrow a biological term, which constitute social revolutions.

Progressivism is, of course, vigorously if not bitterly opposed to reactionism, but it is almost as bitterly opposed to extreme radicalism, as, indeed, moderate radicalism is frequently also. While advanced progressivism can hardly be distinguished from mild or moderate radicalism, we may say that in general the progressive is averse to radicalism because he shares with the conservative a strong sense of order, a high valuation of past experience and a firm conviction in the stability and unchangeableness of human nature. Moreover, where special interests, economic or otherwise, are at stake, the progressive, like the conservative, may fear the results of radical change upon the interests of himself and his class.

Liberalism in a general sense is practically synonymous with progressivism, though the term may connote a slightly less aggressive attitude than is commonly associated with progressivism.

More specifically, current usage applies the term liberal to those who, though they break with conservatism and hold reactionism in contempt, still hold that the main contours of our present political, economic and social life are, if not ideal, at least better than anything to be looked for through revolution or the quick transformations demanded by the radical. The liberal may hold, speculatively, that in ultimate ideal our present mode of life and social organization will be regarded by the peoples of the distant future to be as crude, inefficient and inhuman as we now regard the life of our wholly barbarous forebears; and yet he will reject radical reform or revolution on technological and especially on psychological grounds. His attitude, and there is much to be said for it, both from the standpoint of scientific psychology and from any rationalist's observation of human nature in everyday life, is summarized

in the sentiment: "Yes, all that would be very good and attractive if human nature were different, but it isn't." When it comes to the extreme speculative idealism of a humanistic philosophical anarchist like Bertrand Russell, that is the inevitable sentiment of all, from reactionary to socialistic radical—and doubtless of Mr. Russell himself.

In a still narrower sense, the liberal of to-day, like the economic and political liberals of England and France of the nineteenth century, is one who regards free competition, private initiative and political government as crystallized in the English or American system as approximately ideal. He is naturally averse to reforms leading to government ownership or to socialism and to more government control than is essential to that somewhat traditional and elusive thing, free competition.[2]

The more a term is on everybody's lips the harder it is to define it. This is particularly true of the word "radicalism." Etymology, as usual, gives us little help. The dictionary definitions are figurative and hazy. About all they tell us is that "radical" and "radicalism" carry the double connotation of change and thoroughness. But so may "reactionism." Radicalism and reactionism merely idealize and advocate change in diametrically opposite directions, the one towards the old, the other towards the new. Radicalism means innovation; reactionism suggests literally renovation, a bringing back and renewing of the old.

We may define radicalism as the desire for, and the advocacy of, speedy, deep and thoroughgoing innovative reform or revolution, either touching only certain aspects of social relations and processes or involving the whole social order.

As both social evolution and social revolution have, on the whole, during the modern period, been toward political and social democracy and away from absolutism, authoritarianism and class privilege, radicalism has been, is at present and for a long time will continue to be directed to the project of rapid, accelerated democratization. If applied to a case of extreme economic radicalism like the bolshevist régime in Russia, this statement might be regarded as humorous, in view of the autocratic methods of Lenine and Trotsky. The bolshevist reply is, of course, that these methods are merely a necessary temporary expedient in the service of ultimate democracy. Final proof of the validity or falsity of this excuse lies only in the future.

[2] Perhaps the best brief presentation of this type of liberalism is Woodrow Wilson's "The New Freedom," 1913. Contrast, for example, M. P. Follett's "The New State," 1920. Bryce's "Modern Democracies," 2 vols, 1921, is also suggestive.

It should be noted that two radicalisms, both visioning thoroughgoing innovation, may point in different if not opposed directions. Socialism and anarchism, for illustration, agree only in wishing the abolition of the present social system; further than this, they have little in common, for anarchism, very credulous as to the innate goodness and reasonableness of man, would abolish all coercive forms of social control,[3] while socialism, with less childlike faith in human perfectibility and greater practical insight into the difficulties of economic organization, looks forward, generally speaking, to a very material increase in the amount and effectiveness of social control over the actions of the individual. Much the same kind of opposition exists between moderate socialism and communism. In England, in the first third of the nineteenth century, two radicalisms, Cobdenism (free trade, *laissez faire*) and socialism, were similarly opposed, though they were in agreement in demanding the abolition of the traditional Tory mercantilist economic policies.[4]

In English politics the term "radical" was originally an opprobrious epithet applied by aristocratic Tory reactionists to a group of liberals who did not regard the Reform Bill of 1832 as the last word in the extension of the parliamentary franchise.

Since the world war there has been a noteworthy, and in some quarters, successful, attempt to revive this opprobrious use of the term. The attempt has been especially general in the United States, where the tendency seems to many liberals to be less toward real democracy than it is in England.

The central social conflict of to-day is without doubt the conflict of economic interests. This struggle is waged along two intersecting planes, one of class, the other of nationalistic interests. In these respective planes the conservative and reactionary positions are held by the capitalistic employing class and the nationalists, while the extreme radical positions are held by those who aim at some form of comprehensive economic collectivism and in general are advocates of internationalism. This alignment is by no means mere accident, but is the historical and the logical result of conflict of the interests involved. Be that as it may, however, capitalistic, corporate reactionism stands in determined defense against the massed attacks of radical collectivist internationalism. Thus it becomes easy to associate "patriotism" and "loyalty" with capitalism and nationalism, while "radicalism" is made to carry the

[3] *Cf.*, for example, Bertrand Russell, "Proposed Roads to Freedom," 1919.

[4] Leslie Stephen, "The English Utilitarians," 1900, Vol. III, p. 38. As to the radical democrats in England from 1830 to 1870, see Bryce, "Modern Democracies," 1921, Vol. II, p. 568.

strong implication of disloyalty (pro-Germanism during the war) and of socialism or "bolshevism." By this process of associative emotionalism, consciously aided and stimulated by a none too scrupulous system of well-financed propaganda, "radicalism" and "bolshevism" have been made to mean to the average business man and to many others practically the same thing, and that something to be dreaded and fought against by every available means.

That this uncritical usage is unfortunate, entirely apart from the respective merits of capitalism and socialism or of nationalism and internationalism, a moment's reflection will show. In the first place such usage is the result of combative emotionalism and intolerance, and these sentiments rarely if ever advance the cause either of truth or of human welfare. In the second place such a narrowing of the connotation of the term radical deprives it of significance outside the field of the economic and political struggles and leaves us without a term to denote the thoroughgoing innovative attitude in other phases of human life, for example, in religion, ethics and art.

A still weightier reason against this popular usage is that by no means all the individuals who advocate really radical measures, that is, thoroughgoing innovation in some particular field of human activity, even in the economic, are socialists, or internationalists, much less communists or bolshevists. We should hardly withhold the term radical from the staunch single-taxer, from the advocates of the abolition of the United States Senate or the Supreme Court, or those who would initiate a wide-reaching system of governmental price regulation, divorce by mutual consent, or compulsory education of every normal boy and girl to the age of eighteen. Each of these is (or would be) but a limited radicalism, that is radicalism applicable to only a single part or phase of our social organization, but within the scope of its interest, attention and design each is just as truly radical as is socialism or internationalism. It can hardly be said that the Eighteenth Amendment and the Volstead Act were not radical innovations. Curiously enough, however, popular usage has not taken to calling the prohibitionists socialists.

There is, then, in every field of human sentiment, thought and action a continuous gradation of attitude from reactionism to radicalism. The terms conservatism and radicalism should always be regarded as relative, both to each other and to the standards of valuation or sentiment current at the time. What appears to one person or at a given time or in a given place extreme radicalism may be to another person in another time or place hidebound conservatism. As there are degrees of conservatism, so there are gradations in radicalism. Comprehensive radicalism is revolution-

ary in thought and purpose. In method it may be either revolutionary or reformist. Less comprehensive or thoroughgoing radicalism may be reformist (as distinguished from revolutionary) in both aim and method. In general, history shows fairly well that the radicalism of to-day becomes the liberalism and progressivism of to-morrow and the conservatism of the day after. When the aims of the radicals of a particular epoch are accomplished they usually become conservatives. But however rapidly sentiments and standards of valuation may shift, the radicalism at any time existent is always an attitude which demands thoroughgoing change through conscious innovation.

It may be suggested that a distinction should be made between radical desires and innovative impulses, since in the absence of such distinction all innovators, inventors like Edison or Bell or Westinghouse, all creators of new architectural styles, all those who introduce new models in art or literature, would have to be classified as radicals. It might be convenient to think of thoroughgoing innovation as radical only when advocated or carried out against opposition. Radicalism would then be defined as desire for thoroughgoing innovation opposed by conservative objection and obstruction. While this distinction is logical enough, it has more academic than practical significance.

Distinction between thought or theory and action should be kept in mind—a distinction somewhat more significant in radicalism than in conservatism. Conservative sentiment and conservative conduct may coincide without excessive expenditure of energy. On the other hand, radical sentiment or theory may not result in radical action, because such action means not only doing something but doing it against the whole weight of conservative inertia if not against the violent opposition of interested reactionism. Moreover, radicalism is in a sense a less "natural" attitude than conservatism, because the radical not only has to meet the pressure of conservative inertia and reactionary opposition of other persons but also to overcome the conservative tendencies of his own nature.

Returning to the other end of the attitudinal spectrum, we find that some conservatism is the expression of sincere and relatively unselfish intellectual conviction; that most is the product of mere habit and uncritical fear, and that not a little of it is thoroughly selfish in its motivation and insincere in its expression and reasoning. So far as conservatism is the product of conscious motivation, two primary motives prompt it: the one is selfish, material interest, economic or otherwise, in the established order of things; the other is a temperamental attachment to things-as-they-are. The attachment may or may not be productive of good or logically jus-

tifiable, but the individual always finds, if forced to, what seem to him good and sufficient reasons for it, and hence for the essential propriety and rightness of the things—the ideas, beliefs, institutions and relations—to which he is attached. Sometimes his reasoning may have objective scientific validity, but it is quite as likely to be the type of reasoning for self-defence and self-justification which the psychoanalysts call "rationalization," that is, casuistry.

Because of this fundamental difference in motivation it is desirable, in an attempt to analyze the motives and characteristics of the conservative attitude, to distinguish what we may call, for want of better terms, *interested* conservatism and *disinterested* conservatism. Interested conservatism is motivated by narrowly selfish, egotistical, individual or class interests. The interested conservative invariably has an axe to grind, and it is distinctly his own. The motivation of interested conservatism is mainly, but not entirely, economic. Disinterested conservatism, on the other hand, is an attitude due not to the calculating quality of the "narrower selfishness" or of conscious class interest, but rather to the pervasive influence of the instinct of fear, and of association, imitation, habit and adaptation. It is thus both temperamental and characteristic.[5] Both interested and disinterested conservatism may be observed in the same individual, and they gradate into each other in a manner which makes too sharp distinction between them erroneous.

In a very fundamental psychological and ethical sense, it may be argued that there is no such thing as disinterested conservatism, or, having regard for conscious motivation only, a disinterested attitude of any kind, since we assume those attitudes which correspond to our strongest habits, desires and interests. Any attitude may in this sense be regarded not only as the expression of the nature of the person but as a servant to the functioning of his personality. Whether we have quick and sensitive sympathy or are insensitive and unsympathetic, and whether we are broadly intelligent in finding our own happiness, in conjunction with that of others or are directly, narrowly and unintelligently selfish, it may be maintained (again so far as conscious motivation is concerned) that we always do those things which, under the circumstances present to our appreciation, we deem will give us the most satisfaction.[6] We are

[5] Broadly speaking, psychology calls traits which the individual possesses by reason of organically inherited instincts or tendencies "temperamental"; those which result from environmental influence "characteristic."

[6] No crude hedonism is implied by this statement. It is not assumed that all human motivation or even the major part of it is conscious or that all conscious motivation is intelligent.

not concerned at this point, however, with this broader, deterministic and somewhat unconventional conception of self-interest. Whether all conduct be found in the last analysis to be self-centered or not, the practical fact remains that some people are temperamentally conservative and others so primarily from conscious motives of material self-interest in the narrow sense. And this distinction proves significant and essential to an attempt fairly and objectively to analyze the psychology of conservatism and the influence of conservatism upon social ideals and social achievement.

# THE CENTENARY OF A UNIQUE DISCOVERY

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In science, as in other activities, it is commonly said that there is nothing new under the sun and that there are definite cycles in the conceptions which have been held in the course of human progress. When one reviews the history of any branch of culture, he sees the reappearance of ideas at longer or shorter intervals alternating with periods in which the same ideas are hopelessly out of date. Surveying the numerous instances which fortify this contention, the apparent validity of the general conception of recurrent "fashions" in scientific thought seems established. However, the very fact that progress has been made in explaining natural phenomena indicates that new information is being added to the sum total of knowledge.

From the point of view of fundamental discoveries, the nineteenth century may be called the Golden Age in the history of natural science. The physiological sciences, especially, were benefited by the effective combination of genius and opportunity during this time. The discoveries of Magendie, Beaumont, Bernard Ludwig, Voit, Pawlow and others form the foundation stones upon which rests the modern superstructure of functional, physical and nutritional physiology. And so it is given to us, in this next century, to celebrate the centenary of many epoch-making discoveries in a variety of fields of endeavor.

The constancy of the reaction of the body fluids represents a fundamental physiological property. And yet, while the blood and tissues maintain their approximate neutrality tenaciously, the cells of the mucous membrane of the stomach produce the gastric juice which is relatively strongly acid. Acidity of such strength occurring in any other place in the body would occasion serious results. It is not strange, then, that the announcement of Prout's discovery of "free" hydrochloric acid in the gastric juice in December, 1823, caused a sensation among the scientific men of his day. In order to appreciate the significance of this striking revelation it is well to trace briefly the development of the ideas of gastric digestion up to the beginning of the nineteenth century.

From their own observations, the ancients knew that digestion

consisted, in principle, of converting solid materials to something soluble, or at least semi-fluid. The physical differences between the food ingested and the wastes excreted were perfectly obvious. What forces residing in the body could bring about such a change? It was natural to impute this power to such mechanisms which were familiar, and thus heat, putrefaction, mechanical abrasion and fermentation were variously held responsible for the process of digestion. Toward the end of the dark ages, under the mystic influence of alchemy, Van Helmont suggested that digestion takes place by means of the energy dispensed by the archeus. Sylvius, writing at the same time, thought that gastric digestion is closely similar to ordinary fermentation, and Grew, somewhat later, considered the whole phenomenon to be nervous in character. Contrasted to these fantastic hypotheses was that of Redi, who looked upon digestion in man as being brought about by mechanical means such as occur in the gizzard of birds. At about this time (1681) Borelli reported significant observations on the solution of bone by the gastric juice. Haller,[1] writing in the middle of the eighteenth century, knew that in the stomach food was "digested in an heat equal to that of incubation, imparted by the contiguous heart, liver and spleen" by the various juices found there which produced solution much as "warm water and time do in other situations." Haller observed that "metals themselves, by long stay in the stomach, grow soft, and are eroded" and also that "the juice in the stomach alone, by a continuance of its action, in fishes, dissolves the bones which they devour."

Although there were these hints at the truth with reference to the *modus operandi* of gastric digestion, it remained for the French naturalist Réaumur to initiate systematic experiments on the gastric juice, the results of which were published in 1752. He observed digestive changes *in vivo,* convinced himself that there was no grinding action in the stomach and finally obtained gastric juice by allowing a tame buzzard to swallow and regurgitate metal tubes containing sponges.

Somewhat later (1783) the work of Réaumur was repeated and extended in a series of masterful researches by the Italian monk Spallanzani. As a result of these studies he was convinced of the powerful digestive action of the fluid in the stomach of animals. In addition, he obtained samples of his own gastric juice and repeated his experiments in glass flasks, where he observed the digestion of meat. Some of this fluid kept in a stoppered flask—"ne changea ni de goût ni d'odeur, quoique je l'aye conservé pendent un mois

[1] Haller: "First Lines of Physiology," First American edition, 1803, p. 317, 318, *et seq.*

trés-chaud de l'été.''[2] Spallanzani recognized the antiseptic quality of the gastric juice, but made no suggestions as to the possible cause of it. Both Carminati and Brugnatelli, contemporaries of Spallanzani, had described the acid character of the gastric juice of carnivorous birds. Spallanzani, therefore, requested his colleague Scopoli, a chemist, to analyze some gastric juice. The report sent back stated, among other things, that there were large amounts of ammonium chloride and that with silver nitrate a heavy precipitate was obtained. Scopoli finally concluded that ''le sel marin est produit par les forces vitales, & l'on pourroit soupçonner que l'acide marin est un produit des animaux qui habitent la mer.''[3] Lacking any convincing evidence to the contrary, Spallanzani therefore concluded that the gastric juice was normally neutral. Thus because of the limitations of chemical methods then available, the discovery of the ''free'' hydrochloric acid was missed and not until forty years later was definite proof produced of its existence in the gastric juice.

An interesting contribution to the nature of the acid in the gastric juice was made by John R. Young, an American, in a dissertation submitted to the faculty of the University of Pennsylvania in 1803. Dr. Young relied entirely on his own observations for the facts which he disclosed. Experiments *in vivo* and *in vitro* upon bullfrogs and upon human beings convinced him that the digestive action of the gastric juice was not due to fermentation. By the use of litmus paper and indirectly through testing the solvent action on bones, he found that the fluid in the stomach was acid. Since the gastric juice of a fasting frog was acid, he decided that this acidity did not arise from fermentation but was secreted by the stomach. Obtaining a precipitate when lead acetate was added to the filtered fluid, he concluded that the free acid in the gastric juice was phosphoric, since lead phosphate is precipitated from urine by similar procedure. From silver nitrate a precipitate was obtained on adding gastric juice which was considered by Dr. Young as confirming his previous tests. It was thus by a mere turn of fate in the form of inadequate qualitative analysis that the credit for making an important discovery passed from America to England.

Five years after the presentation of Dr. Young's thesis a youth of twenty-three began the study of medicine in Edinburgh. This young man had, for some reason, not suffered the usual course of schooling applied to boys of that day, but had studied at home and, left to his own inclinations, had gathered much useful classical and

[2] Spallanzani: ''Experiences sur La Digestion,'' Lausaune, 1785, p. 263.
[3] *Ibid.*, p. 308.

scientific knowledge. This early method of acquiring information and an inborn instinct for careful observation seem to have influenced the activities of his mature life to a marked extent, for no sooner had William Prout left the hospitals in London and "set up" in business for himself in the Strand than he began to publish the results of investigations on a wide variety of medical and chemical subjects. He spent considerable time studying the quantity of carbon dioxide emitted from the lungs under various conditions. The chemistry of the urine and amniotic fluid then claimed his attention. He supported Dalton's atomic hypothesis and suggested that all elements were composed of hydrogen atoms. In both 1819 and 1820 he published papers on the nature of urinary calculi and the treatment for gravel. For the next two or three years he busied himself with observing the changes in composition of the egg during incubation. In December of 1823, before the Royal Society, Prout produced his experimental evidence showing that in the gastric juice "the acid in question is the muriatic acid and that the salts usually met with in the stomach are the alkaline muriates."[4]

In order to determine the relative quantities of the various chlorides he proceeded as follows: The stomach of a rabbit killed at the height of digestion was thoroughly extracted with water until nothing more was dissolved. The extract, "which always exhibited strong and decided marks of acidity," was allowed to settle and the clear supernatant fluid divided into four parts. One part was evaporated to dryness and ignited and the chlorides determined in the ash. This was the chloride in combination with fixed alkali. The second part was saturated with potash, ashed and the chlorides determined. This indicated the total amount of hydrochloric acid present. The third part was titrated with potash and the free acidity determined. By adding this to the chloride in combination with fixed alkali and subtracting from the total chlorides, the chloride present as ammonium chloride was measured. Finally, when he failed to obtain a precipitate when barium chloride alone or when ammonia was added he concluded that neither free sulfuric nor free phosphoric acid was present. Using the above procedure, Prout identified free hydrochloric acid in the gastric juice of the dog, horse, calf, hare and man.

The chemical sense and clear line of reasoning which Prout showed in making his experiments were sound, and history has proved that his deductions were correct. Later, Prout concluded that the source of the hydrochloric acid lay in the chlorides of the blood, from which the Cl-(ion) is separated by vital or electrical action and passes into the stomach. Save for some new words

[4] Prout: *Philosophical Trans.*, 1824, p. 45, *et seq.*

given us by Arrhenius, how much farther have we advanced in these past hundred years in explaining the mechanism of formation of hydrochloric acid in the stomach?

In 1826 appeared the account of the classic work of Tiedemann and Gmelin. These authors in substantiating the work of Prout remark:

> Prout gebühret die Ehre der ersten Entdeckung. Aber wir haben sie ebenfalls unabhängig von ihm, in Februar 1824 bei der Distillation verschiedener Magenflüssigkeiten entdeckt, und erst einen Monat nachher kam uns seine Abhandlung über diesen Gegenstand zu Gesicht.[5]

Tiedemann and Gmelin, in addition to finding free hydrochloric acid, claimed to have found free acetic and butyric acids. In 1825 Leuret and Lassaigne, successful competitors of Tiedemann and Gmelin for the prize of the Académie Française, claimed to have found only lactic acid and looked upon Prout's discovery with suspicion. According to them, his chloride determinations were incorrectly done and "Les conclusions du travail de ce chimiste sont donc inexactes."[6]

While on the continent there were partial corroborations by some investigators on the one hand and actual contradictions on the other hand there appeared in 1833 the account of a remarkable series of observations which offered convincing support to Prout's work. In that year Dr. William Beaumont, an American army surgeon, published the results of his experiments on Alexis St. Martin, the now-famous "versuchstier" whom fate had placed in Beaumont's hands while the latter was stationed at an army post in the wilds of upper Michigan in 1822. No part of the phenomenon of gastric digestion was overlooked by this keen observer and it is with interest that we search for his first-hand information on the acid of the gastric juice. In the second series under Experiment 11 appears the following:

> Dec. 14 (1829). At 10 o'clock, P. M., after eighteen hours fasting, introduced tube, and drew off one and one half ounces of gastric juice. It was clear, and almost transparent; tasted a little saltish and acid, when applied to the tongue, similar to thin mucilage of gum arabic, slightly acidulated with muriatic acid. . . .[7]

Beaumont later sent some of the gastric fluid to his friend Professor Dunglison, at the University of Virginia, who examined it

[5] Tiedemann and Gmelin: "Die Verdauung nach Versuchen." (Vol. I, preface p. XII.)

[6] Leuret and Lassaigne: "Récherches Physiologiques et Chimiques pour servir a L'Histoire de la Digestion," Paris, 1825, p. 117.

[7] Beaumont: "The Physiology of Digestion," Second Ed., Burlington, 1847, p. 129.

with the aid of Professor Emmett. These men reported finding free hydrochloric and acetic acids. On distilling, free acid passed over and "the quantity of Chloride of Silver thrown down on the addition of the Nitrate of Silver was astonishing."[8] Thus, some of the most substantial support for Prout's work came from early American investigators.

In 1835, Braconnot, a French chemist, showed that in the alcoholic extract of the fat-free gastric juice he obtained not crystalline zinc lactate but deliquescent zinc chloride, when zinc oxide was added. In spite of these and still other investigations showing that the gastric juice contained "free" hydrochloric acid, opinion was divided and a group of prominent scientists maintained that it was lactic acid which occurred free in the stomach and that the hydrochloric acid was formed from the interaction of the organic acid on the chlorides during the course of the distillation.

In 1852, two years after the death of Prout, appeared the classic monograph of Bidder and Schmidt dealing with the digestive juices and metabolism. In the section on gastric juice appears the following:

> Als Resultat von 18 ubereinstimmenden Analysen ergab sich, dass reiner Magensaft seit 18—20 Stunden nüchterner Fleischfresser nur freie Chlorwasserstoffsäure, und keine Spur von Milchsäure oder anderern organischen Säuren —der Magensaft von Pflanzenfressern neben freie Chlorwasserstoffsäure noch kleine Quantitäten Milchsäure enthält, die indess nur von den stärkemehlreichen Nahrungsmitteln abzuleiten waren. Die Menge letzterer Säure war daher sehr wechselnd, während die der ersten constant erschien.[9]

Furthermore, they state that the hydrochloric acid is produced by the glandular cells in gastric mucosa, thus settling the dispute as to its origin.

The clear-cut procedure of their analyses and the definite statement of their results seem to have united the divided opinions as to the nature of the acidity of the gastric juice. Indeed, our present-day ideas concerning this one point are very little different from those promulgated by these authors. With the work of Bidder and Schmidt the story of the discovery and identification of the hydrochloric acid in the gastric juice may be concluded. While both Prout and Tiedemann and Gmelin detected the "free" hydrochloric acid independently, the fact that the former published his results two years before that of the latter investigators appeared entitles Prout to the honor of the discovery.

Although Prout's claim to fame rests primarily upon his inves-

[8] *Ibid.*, p. 74.

[9] Bidder and Schmidt: "Die Verdauungssaefte und der Stoffwechsel," Leipsic, 1852, p. 44.

tigations in physiological chemistry, he is also remembered for his directive influence in the science of nutrition. In 1834 appeared the eighth Bridgewater Treatise, entitled "Chemistry, Meteorology and the Functions of Digestion considered with Reference to Natural Theology." In this book are stated Prout's views on nutrition. It is natural and proper, he says, for the higher animals to feed upon those lower down in the scale of life. Man, therefore, has as his legitimate source of food all the organisms of creation. Three kinds of foodstuffs are thus ready made for the use of the human animal; namely, the saccharine, the oily and the albuminous. "Such are the three great staminal principles from which all organized bodies are essentially constituted." "Hence, it not only follows, as before observed, that in the more perfect animals, all the antecedent labour of preparing these compounds de novo, is avoided; *but that a diet to be complete, must contain more or less of all the three staminal principles.*" [10]

This is one of the first expressions of the appreciation of the necessity of fat, carbohydrate and protein in the diet, a fact which entitles Prout to a place among the founders of the science of nutrition. Prout's theory that all atoms are composed of hydrogen atoms attracted considerable attention not only during his life but also afterward and has stimulated much of the accurate work that has since been done on atomic weights.

Not only is it unusual to find a person interested in a variety of subjects such as Prout was, but rarely has one man made such important contributions in three fields of scientific endeavor. The earlier students too often allowed their observations to be colored by the prevalent habits of thought, with the consequence that the light of the truth was hidden under the bushel of superstition and religion. Prout's openness of mind enabled him to conceive the idea and his manipulative skill allowed him to put it to experimental test.

[10] Prout: Eighth Bridgewater Treatise, Second Ed., London, 1834, p. 479, 480.

# A SURVEY OF MATHEMATICS AND ASTRONOMY[1]

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## INTRODUCTION

A SURVEY of mathematics and astronomy under the limitations prescribed for this course will permit of only a few general observations concerning the nature, character and contrasts of the two subjects and of their content and human value.

Mathematics is divided into pure and applied mathematics. Pure mathematics is a science of reason and pure reasoning. Applied mathematics receives its facts from observation of the outer universe. It takes or assumes these data.

Astronomy is a physical science. Observation is the first step in a physical science. Interpretation of the observation is the second step. This second step is of a speculative character because it is not observation of facts. It is the mind's reaction. It is what the mind puts into the observation. It is, therefore, of a speculative or metaphysical nature. A large part of what is called "science" is speculation or metaphysics. If the facts have been well observed according to approved methods which assure their correctness, they may be accepted as tolerably certain.

Speculations or interpretations of facts observed, being the activity of the mind upon the facts, and not facts of observation, possess varying degrees of probability, never absolute certainty. They should always be accepted, if at all, with mental reservations. This is in contrast with pure mathematics.

## PURE MATHEMATICS

Pure mathematics is a system of ideas created by reason according to the necessary laws of thought, on the occasion of experience. That is, the mind, by its own activity or spontaneity, and by its own laws, builds up, on the occasion of experience, a system of logically necessarily connected ideas. Absolute certainty is attained in the results. Pure mathematics creates its own objects.

[1] A forty-minute lecture delivered April 23, 1923, before the convocation of the freshman class of Syracuse University in a survey course on fields of knowledge and study.

It does not observe them. This explains the difference in certainty between pure mathematics and astronomy. The former creates its objects, on the occasion of experience, and logically develops the consequences from those objects of its own creation. Experience does not hand over to it its notions of space, for example, although it is experience which first or at some time incites it to act. That the sum of the three interior angles of a plane triangle in a Euclidean space is equal to two right angles is something we do not establish from experience. We have created the concept of triangle. We deduce from this by logical steps the universal result. No plane Euclidean triangle can arise in the future to contradict the result because in the intellectual act we have been able to construct all possible plane Euclidean triangles.

In astronomy it is not so. The mind acts or rather reacts on facts, it is true, but it did not create them. We did not create the objective universe. If we had we would know it with equal certainty. All we have of it is a few facts handed over to us by experience. Our positive knowledge extends only to the cases we have observed. The facts themselves are incomplete.

Pure mathematics is a subjective universe of our own ideal fashioning, and we have it and can develop it as far as we please with certainty, because it is our own creation within ourselves and developed according to the necessary laws of thought. It is an ideal world. God created the outer objective universe. Man created, on the occasion of experience, by the spontaneity or initiative of his own mind, the inner subjective universe of pure mathematics.

While doubtless man's earliest mathematical activity was in his practical intercourse, yet as leisure afforded he began to create this ideal universe within himself. Certain it is that leisure is a necessary condition for the development of mathematical thought. The bombardment of sensations from without must be arrested by strongholds and impregnable fortifications erected by the will in order to protect and shield the mind from the missiles of experience. In contrast, in astronomy, the more missiles of experience the better. In fact observation is its life.

In its development mathematics to-day has gone far beyond the so-called "traditional mathematics," so far, in fact, that the "traditional mathematics," while not overthrown, is so limited and special a portion of the vast field that it can not be taken as the representative of mathematics. A definition of mathematics as it is conceived to-day would be something like this: Mathematics is the science which from given premises draws necessary conclusions. Algebra—which includes arithmetic as a special case—might be defined somewhat in this way: Algebra is the science of the com-

bination of symbols according to previously prescribed laws of combination. Different prescriptions for the laws of combination differentiate the various kinds of algebras from each other. These laws are to-day put at the beginning of each kind of algebra in the form of a set of independent, non-redundant and minimal number of so-called postulates which the symbols must obey in that field in their combinations with each other and which completely characterize and set off that algebraic field from every other one; in other words, completely define the particular field.

Geometry is the science of space and spatial relations. It treats of geometrical forms and their properties. As in the case of algebra, there are various geometries to-day, treating of the different mathematical spaces which the mind of man has created, sometimes grouped under the single generical names of pangeometry, metageometry, etc., comprising such spaces as Euclidean, non-Euclidean, under the forms of parabolic, hyperbolic and elliptic spaces, hyperspaces, space of $n$ dimensions, an Einstein space for use with the theory of relativity, which is simply and easily defined by a system of ten differential equations which must be satisfied in this space, to work with which one must be familiar with the theory of differential invariants and the calculus of variations. In the traditional geometry there are two kinds—a metrical geometry, known as analytic geometry, in which algebraic symbols receive a certain geometrical meaning by convention and algebraic operations are conducted with the symbols and the algebraic results are interpreted geometrically, and a non-metrical geometry, variously known as pure geometry, synthetic geometry, projective geometry, geometry of position, etc., in which no algebra or algebraic calculations but only geometrical intuition and logic are used.

Many and various disciplines have arisen and will still arise unknown and undreamed-of by the old traditional mathematics.

To go farther into the causes of the certainty and universality of mathematics: First, there are definitions. A definition merely states what the thing is, separates it from everything else. It is simple and clear. All terms in it are commonly understood or else have been previously defined. It contains no property of the thing defined. It is what Kant called an analytic judgment. Nothing is affirmed in the predicate that is not logically equivalent with the subject. It is a convertible proposition. Otherwise stated it is an identity. Its form is, A is B. It is sometimes put as B is A, or B is that which is called A. The first form, A is B, in which A is the thing to be defined, is by all means to be preferred. Next come axioms or postulates special to the field. Next, exact logic is used at every step. The method of pure mathematics, with the excep-

tion of necessary syntheses, is in the main deductive. That is, the logical consequences or implications of the thing defined are developed, in a chain of logically and necessarily connected ideas, the final idea necessarily following from the premises.

Aside from its logic, its necessity, certainty and universality, mathematics owes its superior power to its symbolic language, the most powerful language known. It made no great progress until symbolic language was employed. This language enables it to outstrip every other science. An example of this follows: A determinant of the $16^{th}$ order would as a determinant if printed in large figures occupy two thirds of a page. If written out in the ordinary algebraic manner in full, and printed in volumes of 200 pages each, it would require just 4,358,914,560 volumes to contain it. And if libraries four to a block (two on each side of an avenue to a block) and eight blocks to a mile, and each library to hold a million volumes, were built, this determinant avenue would be a little over 136 miles long. It is evident that it could not be read through even once in a lifetime. But as a determinant it can be handled, used and operated upon without difficulty. Thus, by this powerful language one has possession in this single instance (and it is only one such) of all the million volume libraries double lining an avenue over 136 miles long. The necessity, certainty and universality of pure mathematics afford a perfect intellectual satisfaction not experienced in any other field of science.

As to the applications of mathematics we may mention commerce, all business, physics, chemistry, astronomy, biology, psychology, political economy, logic and numerous other fields. In fact, the universe is, in one of its aspects, a mathematical universe. Therefore, this aspect of it can not be reached by the student without the mastery of considerable mathematics. Whoever wishes to go to the bottom of astronomy, physics, chemistry and other fields must be equipped with mathematical tools for penetrating study and investigation. And mathematics in its turn owes much to the stimulus which it has received from these sciences in their demands upon it for farther developments for the solution of their problems.

Architecture and engineering structures call for more or less mathematics. Ships, railroads, steam engines, electric motors, all the machinery of industry, rest ultimately on mathematics. Every science strives to reach the ideal of mathematics. Until it does this to some reasonable degree, it is not yet an exact science, a characteristic of which is ability to predict the future with mathematical exactness within the limits of the errors of observation.

Then mathematics finds an application in its ability for training the mind. It is not perhaps for every one; but for him who

will take it there is no finer training. In England, many of those who are going into the ministry and law quite regularly take all the mathematics they can at the University of Cambridge. The reason for its superiority for training is that it is a pure logic. You can see the mind working according to its necessary laws of thought, that is, you can see the machine running light so far as being cumbered down or cluttered up with objects or matter is concerned. You have a chance to study the machine itself as it runs without material things obscuring the view. Mathematics has also a moral aspect. One knows in it whether he is right or not. He can not deceive himself without knowing the deception. It naturally trains one to honesty, moral probity, straightness and habits of exactness.

Mathematics also exercises the emotion of the esthetic and the beautiful. But this is not for the tyro who takes a course in required mathematics under compulsion and chafes under the exacting discipline of its technique. His prejudice against it blinds him to any of its excellencies. When the technique is so mastered as to become second nature and it no longer irritates, one can appreciate and enjoy the beauty of its truths. In fact, it offers the highest type of intellectual beauty and pleasure.

Mathematics affords one of the best means of training in the art of exact speech. Abraham Lincoln and his immortal Gettysburg speech afford an example of this. When asked by a professor of rhetoric at the close of his speech how he could have trained himself to produce such a masterpiece, Lincoln, without admitting that it was a masterpiece, modestly said that he was accustomed to spend a few minutes each day in reading over propositions in Euclid's Elements of Geometry, a work in which the language is very fine.

Sylvester, a great mathematician, claimed that poetry and mathematics come together in their higher flights. This is doubtless true in their higher flights, but not in their incipient stages, by which both unfortunately are quite sure to be judged by those who properly know nothing of either. As well judge poetry in the incipient stage of mere doggerel or catterel or music in the stage of finger and voice exercises, as to judge mathematics in the stage of mere acquirement and practice of its technique. Of course such judgment has no ultimate value. And there is no question that mathematics and philosophy come together. Royce expected great benefit to philosophy from modern mathematical developments.

Those who decry mathematics as training are people who advertise that they could not handle it or have not advanced far enough to know what they are talking about. Of course one may have a deficiency of mathematical ability and appreciation and still have other ability. One may live with only one lung or one hand or

minus some other organ of the body. He simply deserves our tenderest sympathy. You would not think he would get up on the house top and proclaim this deficiency with pride, and decry the uselessness of having a perfect organism. Yet there are those who do this and thus expose themselves every time they speak and write against the value of mathematical training. It reminds one of the fable of the fox who lost his tail. Being caught by the tail in a trap, he was obliged to come away without his tail, in order to free himself. At the next convocation of the foxes he arose and decried the value of tails. He said he had never realized how useless they were until he lost his. He moved that they all have their useless tails amputated. The proposition received only one vote. His audience were foxes, also. What has been said here of those who decry mathematical training could be said equally well of those who decry the value of any other training subject.

## Astronomy

Astronomy is the science which studies and investigates the outer and objective universe, sometimes called the macrocosm. It is a physical science of observation or an observational science. Therefore, besides the facts observed, it contains a mass of speculations, of varying degrees of probability. Some of its speculations are pretty good investments. Others may or may not turn out so well.

There is a pseudo-science, that is, a sometimes so-called science, which is not science at all, but superstition, humbuggery, fraud, a scheme to take in and fleece the unwary man and the human sucker, which goes by the name of astrology. Don't confuse this with astronomy. Astronomy proceeds by the scientific method, astrology by occult methods which are not open to scientific scrutiny.

Astronomy is one of the oldest of the sciences. The earliest interpretation of the diurnal motion of the stars was that the earth is the center about which all the heavenly bodies revolve. This is the geocentric theory. It was taught by Pythagoras in connection with crystal spheres containing the stars and the planets, the spheres producing the music of the spheres. It is, however, claimed by some that Pythagoras only held this view as an exoteric doctrine for the *hoi polloi,* the common people, and taught the heliocentric theory or sun as the center as an esoteric doctrine for the initiated. Aristarchus held the heliocentric view. Ptolemy reverted to the geocentric theory, and supported it so ably that it lasted several hundred years until Copernicus reinstated the heliocentric idea.

Since Copernicus it has remained as the accepted interpretation of the solar system. However, it has been retouched and precised. Kepler replaced the circles of Copernicus by ellipses as being the orbits of the planets. Newton added the law of gravitation, Einstein proposes the introduction of relativity and farther refinement of gravitational doctrine.

And now the earth, instead of being the center of the universe, has become reduced to a mere celestial bee, buzzing at the rate of 18 miles per second around the sun in the sunlight, while the sun, the king bee carrying along with him his swarm of celestial bees, and formerly the central system of the universe, is buzzing off, at the rate of 12 miles per second, towards a point in the constellation of Hercules.

The problem of astronomy is overwhelmingly vast. As it is a physical science we can not attain certainty, but as the pendulum of speculative interpretation swings back and forth probability of advance increases with the time. It is now quite probable that the solar system consists of the sun, whose distance from the earth and whose mass are known within small limits, no intramercurial planets, Mercury, Venus, the Earth and the Moon, Mars with two moons, about a thousand asteroids or smaller planets, Jupiter the giant planet with nine moons, Saturn with his gorgeous rings and ten moons, Uranus with four moons, Neptune with one moon, a possible transneptunian planet, many comets and several meteor swarms, and the zodiacal light. All these bodies are so well known that the movements of the major ones among them can be predicted with great accuracy for years in advance. Then, besides our solar system there are other solar systems innumerable which form the starry host of heaven, double and multiple stars, clusters, nebulae, both bright and dark, spiral nebulae, possibly island universes, and countless worlds and systems.

Since pure mathematics is our own creation, we are in possession of and may begin with the general and descend to the particular in its domain. On the contrary, since astronomy is a science of observation and can not, like pure mathematics, be created by the spontaneous action of the mind according to the laws of thought, without observations, we must begin with the particular and work up to the general, if we can. We must make the attack on particulars at specific points where there seems to be some chance of success, and hence double stars, nebulae, clusters, Magellanic clouds, proper motions, parallax and star drifts, giant and dwarf stars, stellar temperatures and stellar evolution are for us the portals of the temple of the universe.

Why should one spend time on so vast a problem, in which

years, yes, centuries, of observation are necessary to make some slight advance? So that one may not live even to see the fruits of his labors. Truly astronomy is not a bread-winning occupation. What is it for? I believe that "man does not live by bread alone but by every word that proceedeth out of the mouth of God," in nature as well as in revelation. An old catechism reads something like this: "What is the chief end of man?" Answer: "To know God, to love him and enjoy him forever." I believe that astronomy is for the development and expansion of the soul, that it can satisfy some of its needs in its attempts and aspirations to grasp the reality and meaning of the universe in which it finds itself. To attempt to solve the riddle of the universe is to attempt, feebly though it may be, to understand something of the intelligence, plan, and purpose of the Creator as manifested in his creation, to think his thoughts after him in the starry firmament on high, as well as in the minutest organism which exists. Said Kant, as translated by Sir William Hamilton: "Two things there are, which, the oftener and more steadfastly we consider them, fill the mind with an ever new and rising reverence—the starry heaven above, the moral law within." David said: "The heavens declare the glory of God and the firmament showeth his handiwork." And St. Paul: "The invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead." Dr. Townsend, of Boston University, a theologian and amateur astronomer, maintains that the sun, planets and stars were created for our instruction, profit and pleasure. Whether this is true or not, we may derive instruction, profit and pleasure from them. Poincaré, one of the greatest of modern mathematicians, said: "Astronomy is useful because it raises us above ourselves; it is useful because it is grand; that is what we should say. It shows us how small is man's body, how great his mind, since his intelligence can grasp the whole of this dazzling immensity, where his body is only an obscure point, and enjoy its silent harmony. Thus we attain the consciousness of our power, and this is something which can not cost us too dear, since this consciousness makes us mightier." Says the Book of Genesis: "In the beginning God created the heaven and the earth." God placed man on the earth with the command to subdue and conquer it. And the other sciences are engaged in the conquest of the earth, while astronomy is engaged in the conquest of the skies.

Who could picture the loss to the intellectual development of the world if the stars had been forever shut out from our view by an impenetrable veil of cloud surrounding the earth? Who could estimate the loss to exact science? For while astronomy itself is not

primarily for gain, the nature of its problems, demanding the highest exactitude in investigation, has inspired other sciences and has developed instruments of precision which other sciences have found exactly suited to their needs, and from whose use wealth has resulted in application of science. The story of the mutual stimulus and advantage which astronomy and mathematics have afforded each other, and one of the brightest and most important in the pages of science, is too long to recount here.

Time does not allow a detailed survey of recent and interesting astronomical speculations, regarding star drifts and the two supposed streams of stars, giant and dwarf stars, the treatment of the stars by mathematical representation similar to that used in the kinetic theory of gases, island universes, the order of the evolution of the stars according to spectral type, and the dimensions of the universe.

I have not mentioned in the first place navigation, the laying out of meridians, terrestrial surveys, the ability to find one's way in a desert, the determination of time, standard time, even the determination of an astronomical scale, obtained first by astronomical observations conducted on the earth, for the measurement of the universe, since these, though most useful, are not the highest benefits conferred on man by astronomy.

A survey of the field of astronomy would be incomplete without mention of astronomical instruments. All, so far as optics is concerned, are based on the utilization and development of the laws of reflection and refraction of light and some other laws of physics. There are the telescope, two kinds, refracting and reflecting, in various forms, meridian and zenith transits, the spectroscope, several varieties, the photometer, various forms, the micrometer, the interferometer, photography and measuring machines. While it would be interesting to give detailed descriptions of these, time does not allow.

## Summary

Summarizing: I have tried to explain the difference in character between pure mathematics and astronomy. In the former, we create ideally, on the occasion of experience, and according to the necessary laws of thought, the pure mathematical universe. We have in our intellectual possession and potential grasp all the possible cases. Definitions are clear, postulates mutually independent, logic exact, and to carry out its ideal it has at its command a symbolic language whose power is unlimited. Therefore, we know with a certainty, a necessity and a universality of conviction and therefore with a perfect intellectual satisfaction that belongs to no

other field of science, not even astronomy. For, in the latter we do not create, but have to observe what God has created. Our observation covers only a finite number of cases, and we have not the remaining infinity of unobserved cases in our intellectual possession, hence are not absolutely positive, though by an assumption of the uniformity of nature's laws, which is assumption, and only an object of belief, we expect the infinity of unobserved remaining cases to follow what we assume is the law, which is a considerable expectation, and it must be admitted that astronomy has contributed on the grandest scale to our belief in and expectation of a reign of law in the universe. But this expectation, as a fact, requires confirmatory observation for each extension. Thus the so-called law of gravitation, once accepted for the solar system, was not positively extended to other parts of the universe, until by confirmatory observations on the orbits of binary stars, it appeared to hold. But now to-day this so-called law is in question as to its being the exact interpretation of the observation. Still, it is believed that the ever-oscillating pendulum of speculative interpretation is approaching a limit, and that the probable value of the speculation increases with the time, though it will take an infinite time for it to reach the limit. At least we live in hopes that we are approaching the limit with the advance of time.

We have shown that mathematics is required by every exact science, that it furnishes the ideal and goal of every science which aims to be exact, and that its applications are myriad in fields of human endeavor. We have cited its availability for training, its relation to the moral and the beautiful, to poetry and philosophy.

We have shown that astronomy has as goal a knowledge of the Creator in one aspect of the beauty and grandeur of the universal reality and its meaning, that without the stars we should never have sensed this aspect at all, that it makes us modest on the one hand by showing us our infinitesimal proportions, and on the other hand elevates and inspires us by the majesty of the intellectual grasp which it challenges us to believe we can attain. We have shown its stimulating effect on other sciences, and how they have reaped rewards from its developments. And, lastly, we have cited its everyday practical usefulness in human affairs.

# THE INTERIOR OF A STAR[1]

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ON December 13, 1920, the angular diameter of a star was measured for the first time in history with an apparatus devised by Professor A. A. Michelson. Hitherto every star had appeared as a mere point of light, and no test had been able to differentiate it from a geometrical point. But on that eventful evening a 20-ft interferometer constructed at the Mount Wilson Observatory was turned on the star Betelgeuse, and the measurement revealed that this star had a disc 1/20 of a second of arc in diameter—about the size of a halfpenny 50 miles away. The distance of Betelgeuse is known roughly (unfortunately it can not be found so accurately as the distance of many stars), so that we can convert this apparent size into approximate actual size. Betelgeuse is not less than 200 million miles in diameter. The orbit of the earth could be placed entirely inside it.

Historically this achievement should come rather towards the end than at the beginning of my discourse; but I am to occupy your time with a great deal of theory, and so I thought it well to start with one ascertained fact. The stars are not limited to objects of comparatively small bulk like the sun; there are among them individuals truly gigantic in comparison. We can add another step to the astronomical multiplication table—a million earths make one sun; ten million suns make one Betelgeuse.

This is a comparison of volume, not of amount of material. It leaves open the question whether in order to obtain one of these giants we should take the material of ten million suns rolled into one, or whether we should take the material of the sun and inflate it to ten million times its present size. There is no doubt that the latter answer is nearer the truth. Betelgeuse, I admit, contains more matter than the sun (perhaps 50 times as much); but in the main its vast bulk is due to the diffuseness with which this material is spread out. It is a great balloon of low density, much more tenuous than air, whereas in the sun the material is compressed to a density greater than water.

[1] Lecture given before the Royal Institution of Great Britain, February 23, 1923.

Whether the star is one of these balloon-like bodies or whether it is dense like the sun depends on the stage of its life at which we catch it. It is natural to think that the stars gradually condense out of diffuse material, so that they become denser and denser as their life history proceeds. We can now see in the heavens samples of every stage in the development of a star. The majority of those seen with the naked eye are in the early diffuse state; that is not because these young stars are really more numerous, but because their great bulk renders them brighter and more conspicuous. What I shall have to say about the inside of a star refers chiefly to the young diffuse stars—the *giant stars* as they are called. The reason is that we understand much more about the properties of matter when it is in the condition of a perfect gas than when it is condensed; although the difficulties of treating a dense star like the sun are not insuperable, we have naturally made the most progress with the easier problem of giant stars.

We only observe the physical conditions of the surface of a star, and at first it might seem impossible to learn anything about the conditions in the interior. Consider, for example, the question of temperature. The nature of the light received from Betelgeuse teaches us that the temperature is 3,000° C., not an extravagantly high temperature judged even by terrestrial standards. But this refers, of course, to the layer near the surface from which the observed light is coming; it is just the marginal temperature of the furnace, affording no idea of the terrific heat within. I shall not attempt to explain in detail how we manage to calculate the inside temperatures; but I can perhaps show that there is a clue which can be followed up by appropriate mathematical methods.

Elasticity is a well-known property of a gas, familiar to everybody through its practical application in the pneumatic tire. What gives the gas its elasticity or expansive force is its heat—that is to say, the energy of motion of its molecules hastening in all directions and continually tending to spread apart. The greater the heat the greater the expansive force. Now, at any point inside the star a certain condition of balance must be reached; on the one hand we have the weight of all the layers above pressing down and trying to squeeze closer the gas inside; on the other hand we have the elasticity of this inside gas trying to expand and force the upper layers outwards. Since neither one thing nor the other happens, and the star remains practically unchanged for hundreds of years, we must conclude that these two tendencies just balance. At each point the elasticity, and therefore the heat, has to be of the exact amount needed to bear the weight of the layers above. That is the principal clue by which we determine how much heat there must be at various depths inside the star.

The internal temperature depends on the particular star considered, but it is generally from 2 to 20 million degrees at the center. Do not imagine that this is a degree of heat so vast that ordinary conceptions of temperature have broken down. These temperatures are to be taken quite literally. Temperature is a mode of describing the speed of motion of the ultimate particles of the matter. In a mass of helium at ordinary temperatures the average speed of the atoms is rather under 1 mile per second; at 4 million degrees it is 100 miles per second. This is a high speed, but not a speed to feel uncomfortable over. Some weeks hence Sir Ernest Rutherford will be lecturing to you about atoms of helium moving at 100,000 miles a second. I can not vie with him. I usually find that my physical colleagues are rather disappointed with our jog-trot atoms in the stars.

We must imagine, then, a typical giant star as a mass of material with average density about that of air swollen to at least a thousand times the bulk of the sun. The atoms of which it consists are rushing in all directions with speeds up to 100 miles a second, continually colliding and changing their courses. Each atom is being continually pulled inwards by the gravitation of the whole mass, and as continually boosted out again by collision with atoms below. The energy of this atomic motion constitutes a great store of heat contained in the star; but this is only part of the store. The star contains a store of another kind of heat, ethereal heat, or ether-waves like those which bring to us the sun's heat across 90 million miles of vacant space. These waves also are hastening in all directions inside the star. They are encaged by the material, which prevents them leaking into outer space except at a slow rate. An ether-wave making for freedom is caught and absorbed by an atom, flung out in a new direction, and passed from atom to atom; it may thread the maze for hundreds of years until by accident it finds itself at the star's surface, free now to travel through space indefinitely, or until it ultimately reaches some distant world, and perchance entering the eye of an astronomer makes known to him that a star is shining.

The possession of this double store of heat is a condition which we do not encounter in any of the hot bodies more familiar to us. It is a new phase of matter beyond the reach of laboratory experiment, although happily the theory is so simple that there can not be much uncertainty as to behavior. It is true that a red-hot mass of iron contains a little of this ethereal heat in addition to the heat comprised in the motion of its molecules, but it is less than a billionth part of the whole. Only in the giant star does the ethereal portion rise to importance. A red-hot metal emits ethereal heat,

but it keeps no appreciable store; it converts the material heat into this form as it is required for use. The star rejects this hand-to-mouth method; and although it is continually changing elements of heat from one form to the other it keeps a thousand years' supply always in readiness, and emits its radiation by leaking ethereal heat from the store. In older theories this feature was not realized; it was supposed that convection currents must exist continually bringing up hot matter from the interior to replace the surface-matter which had radiated and cooled. But now it is seen that the difficulty is rather in the other direction—how does the star dam back the store of ether-waves so that they do not escape from it faster than we observe? This change of view has necessitated modifications of the older theories of Lane and others, and has on the whole considerably simplified the problem.

In the hot bodies of the laboratory the heat is almost entirely in the material form, the ethereal portion being insignificant. In the giant stars the heat is divided between the two forms in roughly equal amounts. Can we not imagine a third condition in which this time the heat is almost wholly ethereal, the material portion being insignificant? We can imagine it no doubt; but the interesting, and I believe significant, thing is that we do not find it in nature.

You have heard of the pressure of light—that light actually has mass and weight and momentum, and exerts a minute pressure on any object which obstructs it. A beam of light or ether waves is like a wind, a very minute wind as a rule; but the intense ethereal energy inside the star makes a strong wind. This wind distends the star. It bears to some extent the weight of the layers overhead, leaving less for the elasticity of the gas to bear. That of course has to be taken into account in our calculation of the internal temperatures—making them lower than the older theory supposed. Just as ether and matter share the heat-energy between them, so the ethereal wind and the material elasticity share the burden of supporting the weight of the layers above. We are able to calculate the proportions in which they share it. To a first approximation the same proportion holds throughout nearly the whole interior, and the proportion depends only on the total mass of the star, not on the density or even on the chemical composition of the material. Moreover, in order to make this calculation we do not need any astronomical knowledge; all the constants in the formula have been determined by the physicist in his laboratory. We need to know the average molecular weight of the material, but I shall tell you later how we are able to fix that approximately in spite of not knowing what elements to expect in the star's interior; that happens to be one of the benefits of dealing with very high temperatures.

Let us imagine a physicist on a cloud-bound planet, who has never heard tell of the stars, setting to work to make these calculations for globes of gas of various dimensions. Let him start with a globe containing 10 grms., then 100 grms., 1,000 grms., and so on, so that his *n*th globe contains $10^n$ grms. They mount up in size rather rapidly. No. 1 is about the weight of a letter; No. 5, a man; No. 8, an airship; No. 10, an ocean liner; after that comparisons are difficult to find. The following table gives part of his results:

| No. of Globe | Ethereal Pressure | Material Pressure |
|---|---|---|
| 30 | 0.00000016 | 0.99999984 |
| 31 | 0.000016 | 0.999984 |
| 32 | 0.0016 | 0.9984 |
| 33 | 0.106 | 0.894 |
| 34 | 0.570 | 0.430 |
| 35 | 0.850 | 0.150 |
| 36 | 0.951 | 0.049 |
| 37 | 0.984 | 0.016 |
| 38 | 0.9951 | 0.0049 |
| 39 | 0.9984 | 0.0016 |
| 40 | 0.99951 | 0.00049 |

You will see why I omit the rest of the table; it consists of long strings of 0's and 9's. But for the 33rd, 34th and 35th globes the table gets interesting; and then lapses back into 9's and 0's again. Regarded as a tussle between ether and matter to control the situation, the contest is too one-sided to be interesting, except just from Nos. 33 to 35, where something more exciting may be expected.

Now let us draw aside the veil of cloud behind which our physicist has been working, and let him look up into the skies. He will find there a thousand million globes of gas all of mass between the 33rd and 35th globes. The lightest known star comes just below the 33rd globe; the heaviest known star is just beyond the 35th globe. The vast majority are between Nos. 33 and 34, just where the ethereal pressure begins to be an important factor in the situation.

It is a remarkable fact that the matter of the universe has aggregated primarily into units of nearly constant mass. The stars differ from one another in brightness, density, temperature, etc., very widely; but they all contain roughly the same amount of material. With a few exceptions they range from ½ to 5 times the mass of the sun. I think we can no longer be in serious doubt as to the general cause of this, although the details of the explanation may be difficult. Gravitation is the force which condenses matter; it would if unresisted draw more and more matter together; building globes of enormous size. Against this, ethereal pressure is the main disruptive force (doubtless assisted by the centrifugal force of the star's rotation); its function is to prevent the accumulation of large masses. But this resistance, as we see, only begins to be serious

when the mass has already nearly reached the 33rd globe, and if indeed it is efficacious, it will stop the accumulation before the 35th globe is reached, because by then it has practically completely ousted its more passive partner (material pressure). We do not need to know exactly how strong the resistance must be in order to prevent the accumulation, because when once the resistance begins to be appreciable it increases very rapidly, and will very soon reach whatever strength is required. All over the universe the masses of the stars bear witness that the gravitational aggregation proceeded just to the point at which the opposing force was called into play and became too strong for it.

It was shown by Homer Lane in 1870 that as a gaseous star contracts its temperature will rise. Betelgeuse is typical of the first stage when the temperature has risen just far enough for the star to be luminous. It will go on contracting and becoming hotter, its light changing from red to yellow and then to white. But evidently this can not go on indefinitely. When the condensation has proceeded far enough, the material will be too dense to follow the laws of a perfect gas. A different law then begins to take control. The rise of temperature becomes less rapid, is checked, and finally the temperature falls. We can calculate that the greatest temperature is reached at a density of about 1/4th to 1/3rd that of water. The sun is denser than water, so that it has passed the summit, and is in the stage of falling temperature. So long as the temperature is rising, the brightness of the star scarcely changes. It is becoming hotter but smaller. Calculation shows that the increased output of light and heat per square meter of surface and the decreased area of the surface very nearly counteract one another, so that the total output remains fairly steady. But on the downward path the falling temperature and diminishing surface both reduce the light, which falls off rapidly between the successive stages or types which we recognize. That is entirely in accordance with what is observed to happen.

Taking any level of temperature, a star will pass through it twice, once ascending and once descending. In the main we have been in the habit of classifying stars according to their surface temperature, because it is on this that the spectral characteristics of the light, its color and the chemical elements revealed chiefly depend. But that classification mixes together stars from an early ascending stage and from a later descending stage. For example, a star like Betelgeuse, just beginning its career, is put in the same class with a dense red star, which has run its course and reached its second childhood. They are both red stars of low temperature, and that was good enough for the early attempts at classification. Sir

Norman Lockyer always stoutly maintained the existence of the ascending and descending series, but he was almost alone among spectroscopists in this. He did not actually succeed in separating the ascending and descending stars, though sometimes he came very near to the right criterion. We owe to Russell and to Hertzsprung the actual separation. They discovered it not by spectroscopy, but by measuring the absolute brightness of stars; the greater brightness of the ascending stars, due to their large bulk, easily distinguishes them from the descending stars, at any rate in the low temperature groups. At the highest temperatures the two series merge into one another.

The disentangling of the two series and the recognition of the true sequence of stellar evolution is probably the most revolutionary and far-reaching of recent discoveries in stellar physics. It began to oust the older view about 1914. It is worth noticing that it was found from observations coming under the province of the older astronomy, and not what is generally called astrophysics. The data were parallaxes, proper motions, double star orbits, etc. The spectroscopists had been misled as to the order of evolution, and it was left to the rival branch of astronomy to show the way; but they were not to be outdone for long. Adams and Kohlschütter have found an easy spectroscopic method for distinguishing the ascending and descending stars. Although our main purpose this evening is to grope in the interior of a star, perhaps we may emerge at the surface for a moment to consider what is the difference of surface condition of a diffuse and condensed star, respectively, which enables the spectroscope to distinguish between them.

The state of the outermost layers of a star can, it would seem, be influenced by only two factors: (1) the intensity of the stream of radiant energy crossing through them, and (2) the intensity of gravitational attraction holding them to the star. The former is measured by the effective temperature, so that we have the two variable factors, temperature and gravity. The spectrum presumably will vary as the conditions governed by these factors vary. We must not expect to be able to classify the spectra accurately in a single sequence; they can vary in two directions. The ordinary classification depends principally on the temperature factor; we may call this the longitudinal sequence. Adams's new method aims at disentangling the transverse sequence corresponding principally to the gravity factor. We may say that his method is really a way of finding the value of gravity at the surface of a star, although it is not yet possible to put the value into actual numbers. Clearly gravity will be smaller in the diffuse stage than in the dense stage, on account of the greater distance from the center to the surface.

The effect of lowering gravity is to make the density smaller at corresponding temperature. This introduces an important change in the state of the gas, *viz.*, ionization. At moderately high temperatures the atoms begin to lose one or more of their most loosely attached electrons, a process called ionization. Ionization is facilitated by low density, and prevented by high density. The theory of ionization in stellar atmospheres has been chiefly worked out by M. N. Saha, who has arrived at many interesting results. Here we need only remark that the ionized atoms give rise to different spectra, which have long been distinguished from the spectra of the neutral atoms. The lower density in the atmosphere of diffuse stars should strengthen the "enhanced" lines due to ionized atoms, compared with the "arc" lines due to neutral atoms. The difference in general is not very large, but the atoms of certain elements for which the conditions are most critical are specially sensitive to the change of density. This is the criterion which Adams and Kohlschütter found empirically, and it distinguishes quite easily the ascending and descending series. To a limited extent it also distinguishes the larger and smaller stars within the same series.

Although the stars begin to shine on reaching a temperature of about 3000°, and return to this temperature at the close of their luminous existence, they do not all climb the temperature-ladder to the same height. The more massive stars climb higher than the light stars. We can to some extent calculate the height to which they will go, but I am afraid the figures at present are very uncertain, though there is hope of improving them before long. The sun's surface temperature is now about 5900°. I do not think that it ever went higher than 6600°; it had not sufficient mass to go beyond. Sirius, nearly 2½ times as massive as the sun, has climbed to 11,000°, and at the moment is practically at its maximum, having only just turned downward. Still hotter stars, like Rigel, are known, and these must be more massive still. At the other end of the scale a star of mass less than 1/7th of the sun would not be able to reach 3000°, and could scarcely be luminous; but in any case such small masses would be formed very seldom, for the reason explained earlier in this lecture. It is a well-known fact that hot stars on the average are more massive than cool stars. We see that this is accounted for by the smaller stars being weeded out as the temperature-standard is raised.

We have hitherto pictured the inside of a star as a hurly-burly of atoms and ether waves. We must now introduce a third population to join in the dance. There are vast numbers of free electrons —unattached units of negative electricity. More numerous than the atoms, the electrons dash about with a hundred-fold higher

velocity, corresponding to their small mass, which is only 1/1850th of a hydrogen atom. These electrons have come out of the atoms, having broken loose at the high temperature here involved. An atom has been compared to a miniature solar system: a composite central nucleus carrying positive charge corresponds to the sun, and round it revolve in circular and elliptic orbits a number of negative electrons at comparatively large distances, corresponding to the planets. We know the number of satellite electrons for each element: sodium has 11, iron 26, tin 50, uranium 92. Our own solar system, with eight revolving planets, represents an atom of oxygen. The thermodynamical theory, due mainly to Nernst, permits us to calculate roughly how many of these break loose under given conditions of temperature and density; and in a typical star a large proportion of them must have become free.

This condition solves for us our chief difficulty as to the molecular weight of stellar material. We need to know it in order to perform our calculations as to the state of the star; and at first sight it might seem hopeless to arrive at the molecular weight without knowing the elements which constitute the bulk of the material. But suppose first that the temperature is so high that all the satellite electrons have broken away. An atom of sodium will have separated into 12 particles, *viz.*, 11 electrons and 1 mutilated atom; its atomic weight 23 is divided between 12 independent particles, so that the average weight of each is $23/12 = 1.92$. Next take iron; the atomic weight 56 is divided between 27 particles: average 2.07. For tin we have 119 divided by 51: average 2.34. For uranium 238 divided by 93: average 2.56. It scarcely matters what element we take; the average weight of the ultimate particles (which is what we mean by the molecular weight) is always somewhere about 2. If only the stars were a bit hotter than they actually are it would make our task very easy. Unfortunately they are not hot enough to give complete separation, and the actual degree of separation will depend on the temperature of the star, thus introducing a difficult complication. Generally at least half the electrons are detached, and the molecular weight must be taken between 3 and 4. I hope that the theory of this dissociation of electrons will be improved, because at present that is the chief bar to rapid progress with the theory of stellar constitution. It is a great help to know that the molecular weight is between 3 and 4; but we have reached a stage when it is becoming necessary for progress to know it for each star within much closer limits.

We pictured a physicist on a cloud-bound planet who was able from laboratory data to predict how large would be the masses into which the material of the universe must aggregate. Let us now set

him a harder task. We inform him that we have observed these masses of gas, and, choosing one equal, say, to his 34th sphere, we ask him to predict how brightly it will shine. I have already mentioned that the star keeps practically the same brightness so long as it is a perfect gas ascending in temperature, so it should not be necessary to give the physicist any data except the precise mass. To use the same plan as before, we imagine a series of lamps of 10 candle-power, 100 candle-power, 1000 candle-power, and so on; and his task is to pick out which lamp in this series corresponds approximately to the star. I believe that it is now possible for him to perform this task, and to pick out (correctly) the 31st lamp. But for this purpose it is not enough that he should know all about the heat stored in the interior of the star; the brightness of the star depends on the rate at which the ether waves are leaking out, and that introduces a new subject—the obstructive power of the material atoms which dam back the radiant flow.

Another name for this obstructive power is *opacity*. A substance which strongly obstructs the passage of light and heat waves is said to be opaque. The rising temperature towards the center of the star urges the heat to flow outwards to the lower temperature level; the opacity of the material hinders this flow. The struggle between these two factors decides how much light and heat will flow out. We have calculated the internal temperature-distribution, so that we know all about the first factor; if, then, we can observe the outward flow which occurs, that should settle the value of the second factor—the opacity. The outward flow is capable of observation, because it constitutes the heat and light sent to us by the star.

One of the troubles of astronomy is that our information about the stars is so scattered. We know the mass of one star very accurately, but we do not know its absolute brightness; we know the brightness of another, but not its mass; for a third we may have an accurate knowledge of the density, but nothing else. For Sirius, Procyon and α Centauri our knowledge is fairly complete and accurate; but none of these are giant stars in the state of a perfect gas, and they are therefore useless for the present discussion. But within the last year we have been fortunate enough to obtain complete and very accurate information for one of the giant stars, Capella. This is another of the benefits which astronomy has derived from Professor Michelson's interferometer method of observation. The brighter component of Capella (which is a double star) has a mass 4.2 times that of the sun, and a luminosity 160 times greater. We can use these facts to calculate the opacity of Capella in the way I have described; it turns out to be 150 in C.G.S. units. To illustrate the meaning of this, let us enter Capella and find a

region where the density is that of the terrestrial atmosphere we are accustomed to; a slab of this gas only 6 inches thick would form an almost opaque screen. Only 1/20th of the radiant energy falling on one side would get through to the other, the rest being absorbed by the gas.

It seems at first surprising that 6 inches of gas could stop the ether waves so effectually, but we might have anticipated something like this from general physical knowledge. We give different names to ether waves according to their wave-length. The longest are the Hertzian waves used in wireless telegraphy; then come the invisible heat waves, then light waves, then photographic or ultra-violet waves. Beyond these we have X-rays, and finally—the shortest of all—the $\gamma$-rays emitted by radioactive substances. Where in this series are we to place the ether waves in the interior of a star? It is solely a question of temperature, and the ether waves at stellar temperatures are those which we call X-rays—more precisely, they are very "soft" X-rays. Now X-rays, and soft X-rays especially, are strongly absorbed by all substances. The opacity which we have found in Capella is of the same order of magnitude as the opacity of terrestrial substances to X-rays measured in the laboratory.

The following table shows a few of the laboratory results compared with the astronomical value for Capella:

| Wave-length (A) | Absorption-coefficient (opacity) in | | | |
|---|---|---|---|---|
| | Aluminium | Iron | Silver | Capella |
| 0.5 | 2 | 14 | 10 | ..... |
| 0.95 | 11 | 80 | 72 | ..... |
| 1.1 | 21 | 125 | 86 | ..... |
| 1.3 | 31 | 205 | 152 | ..... |
| 2.3 | 136 | ..... | ..... | ..... |
| 10.0 | ..... | ..... | ..... | 150 |

We have been performing an investigation of the absorption of X-rays in a star, parallel to investigations on the same subject made in the laboratory. In one respect the physicist has a big advantage because he can vary the material experimented on, whereas we have to be content with the material, whatever it is, composing the stars. But, as you see from the table, the physicist is also interested in finding how the absorption changes for different wave-lengths. We can follow him in this, and even do better than he, because he is restricted by certain practical difficulties to a narrow range of wave-length, whereas we can explore a range of wave-length cov-

ering a ratio of at least 10 to 1 by using stars of different temperatures. It is true that our results are not yet very accurate; we have only one star, Capella, for which a really good determination is possible, but for other stars rough values can be found. The terrestrial results indicate an extremely rapid change of absorption for slight alterations of wave-length (as is seen from the table); the astronomical results, on the contrary, give a nearly steady absorption-coefficient. We can not yet detect certainly whether it increases or decreases with wave-length; at any rate, there is nothing like the rapid change shown in the foregoing table. This profound discrepancy between astronomical and laboratory results leads us to inquire more deeply into the theory of absorption in a star. It will be found that there is a good reason for it.

We have been taking advantage over our cloud-bound physicist by having a preliminary peep at an actual star. We are not going to allow *him* to do that. He must not use astronomical observations to determine the opacity, but must be able to predict the astronomical value either from pure theory or from terrestrial experiments. This study is of special interest because it plunges us at once among those problems which are most exercising practical physicists at the present time. We started to explore the interior of a star; we shall presently find ourselves in the interior of an atom.

It is now generally agreed that when ether-waves fall on an atom they are not absorbed continuously. The atom lies quiet, waiting its chance, and then suddenly swallows a whole mouthful at once. The waves are done up in bundles called quanta, and the atom has no option but to swallow the whole bundle or leave it alone. Generally the mouthful is too big for the atom's digestion, but the atom does not stop to consider that. It falls a victim to its own greed—in short, it bursts. One of its satellite electrons shoots away at high speed, carrying off the surplus energy which the atom was unable to hold. The bursting could not continue indefinitely unless there were some counter-process of repair. The ejected electrons travel about, meeting other atoms; after a time a burst atom meets a loose electron under suitable conditions, and induces it to stay and heal the breach. The atom is now repaired and ready for another mouthful as soon as it gets the chance.

From this cause a big difference arises between absorption of X-rays in the laboratory and in the stars. In the laboratory the atoms are fed very slowly; the X-ray bundles which they feed on can only be produced by us in small quantities. Long before the atom has the chance of a second bite it is repaired and ready for it. But in the stars the intensity of the X-rays is enormous; the atoms

are gorged and can not take advantage of their abundant chances. The consumption of food by the hungry hunter is limited by his skill in trapping it; the consumption by the prosperous profiteer is limited by the strength of his digestion. Laboratory experiments test the atom's skill in catching food; stellar experiments test how quickly it recovers from a meal and is ready for another. That is why the absorption follows a different law in the two cases.

To predict the stellar absorption-coefficient we must accordingly fix attention on the rate of repair of the burst atoms. The atom is wandering about advertising a vacancy for an electron, and numbers of ejected electrons are rushing about on holiday. Many electrons will come up, look at the situation, and go off again. How is the atom to trap the electron into taking up the situation? I will give you the solution of this problem, which I am inclined to think fairly probable, though I have not found many who agree with me. We may compare the electron to a stray planet entering the solar system from outside, bearing in mind, however, that the planets (satellite electrons) must be supposed to repel the invader, and the sun (positive nucleus) attracts it. Dynamics teaches us that provided no actual material collision occurs the intruder will scarcely ever be captured, but after stirring up things a little will retreat again towards infinity. There are exceptions, as when the sun and Jupiter conspire to capture a comet, but these would be very rare in the conditions corresponding to an atom.[2] Mere delicate persuasion being of no avail, there seems nothing left but for the atom to secure its electron by brute obstruction. For this reason I take the view that usually the capture of an electron occurs through its running against the positive nucleus of the atom. This nucleus has a highly complicated structure, the iron nucleus, for example, consisting of eighty-six distinct charges arranged in some kind of equilibrium. If by accident an electron runs full tilt into this packed mass, it will agitate it and lose energy in so doing. It will rebound no doubt, but with smaller velocity, insufficient to carry it out of the sphere of attraction of the atom.[3] By a process of exclu-

[2] In some cases the intruder would turn the tables by carrying off a regular planet, thus compensating for the occasions when it was itself captured. Probably, as regards repair of the atom, as much harm as good would be done on the average.

[3] The kinetic energy at the moment of collision with the nucleus is enormously greater than the kinetic energy before entering its sphere of attraction; so that a very small *proportionate* change of kinetic energy by collision would wipe out the original energy of the electron. The imperfect elasticity of the collision is a dynamical consequence of the complex structure of the nucleus. A collision of two simple charges may be perfectly elastic, except that that would apparently prevent a hydrogen nucleus from ever recovering its electron.

sion this seems the only method consistent with dynamical laws by which the atom can secure the electron needed for its repair. Therefore I have concluded that the actual electron trap is none other than the positive nucleus—a region at the center of the atom known to be about $10^{-12}$ cm. in radius. It must be remembered that the nucleus attracts the electrons, and will sweep into the trap many which were not initially aimed at it.

This theory has been adversely criticized, mainly on the ground that it is entirely accordant with the laws of dynamics. At first sight that might not seem a grave objection, but we have got so used to the atom behaving in a way which violates the classical laws that any theory which does *not* violate them is liable to be viewed with suspicion. Whilst admitting that there are uncertain possibilities in the mysterious region in the interior of an atom, we must note that the present problem belongs to a class of investigations in which the usual dynamical laws are applied by physicists, often with much success. It concerns the motion of a free electron—not yet forming part of any permanent quantised system—a problem which occurs in the theory of conduction of electricity in metals, in thermionic phenomena, and in the scattering of $\alpha$ and $\beta$ particles. In these problems physicists are accustomed to assume (rightly or wrongly) that the classical laws of dynamics are observed, and we have only followed their (good or bad) example. In particular, in Rutherford's experiments on scattering, the classical laws of force are found to hold good almost to the boundary of the nucleus itself. There seems to be a fair presumptive evidence that our stellar problem should be attacked in the same way, although we admit that unknown circumstances may intervene.[4]

The strong point in our favor is that this theory actually does give the value of the absorption-coefficient agreeing with astronomical observation. Thus, for Capella the calculated value is 110, as compared with the observed value 150. There are certain doubtful factors which permit of the result being varied by a factor 2, or possibly 3, and we lay no stress on the precise accordance. But it appears to be possible to predict on this hypothesis the brightness of a star of known mass like Capella to within a magnitude—which amply solves the problem proposed to our physicist on the cloudy

[4] Whilst the fast-moving particles undoubtedly penetrate the atom in the way we have assumed, it is held by some that slow-moving electrons (as in the stars) are turned back at the surface. The idea seems to have originated at a time when the positive charge of the atom was thought to be a large sphere co-extensive with it; and it seems out of keeping with modern views. It is ignored in current theories of conduction of electricity. Even if it were conceivable that a neutral atom could so ward off an electron, the strongly positive atoms in the stars could scarcely exclude it.

planet. It may be added that the theory also explains why the absorption in giant stars is nearly independent of the wave-length; but that is a more elementary result, which becomes apparent as soon as we realize that the problem is concerned with the rate of repair of the atoms. Many alternative theories of the conditions of repair would lead to the same conclusion.

The store of ethereal heat and the store of material heat in the star may be compared to the accumulators of a power station. We have not yet discovered the dynamos. The accumulators would run down in a few thousand years if they were not replenished. What is the source of the energy maintaining (and during the ascent of temperature increasing) this internal store? We believe now that the source is sub-atomic energy. One theory is that inside the star the simpler elements are gradually being built up into more complex elements, and energy is liberated in the process; a more drastic view is that matter is being entirely annihilated, setting free the whole of its energy of constitution. Taking the first theory, the most conspicuous known case is in the formation of helium from hydrogen. We do not know how to make helium from hydrogen, but we know that it is so made; we know also that 0.8 per cent. of the mass disappears in the process, and this must be the mass of the energy—ether waves—liberated when the change occurs. Ether waves weigh very light, and the energy available from this source is colossal. If 5 per cent. of the star consists of hydrogen, which turns into helium as a first step in the formation of the higher elements, that would provide energy sufficient for all reasonable demands.

We might, perhaps, expect that the earliest stars would consist almost entirely of hydrogen, the evolution of the higher elements having little chance of beginning until the interior became hot enough to stimulate the process. But a difficulty arises here. For astronomical reasons it seems impossible to admit that even the earliest stars contain more than a very moderate proportion of hydrogen. I have referred to the fact that our calculations have been practically independent of the chemical constitution of the star; but one reservation ought to have been made—*provided it is not made of hydrogen.* Hydrogen gives results differing widely from all the other ninety-one elements. To assume hydrogen as the material would in most cases destroy the general accordance of theory and observation; indeed it is a way of realizing the goodness of this general accordance to note how it disappears when hydrogen is substituted instead of a normal element. I think therefore that the process of element-building from protons and electrons must have begun before the stellar stage is reached. This is a curious

detached piece of knowledge to have come across in exploring the interior of a star—to be able to deny that it is mainly composed of hydrogen, though any of the other ninety-one elements may be present to any extent; and it is still more curious that hydrogen should be the element with which we were tempted to build the stars, so that this apparently random denial hits the mark.

Admixture of hydrogen diminishes the proportion of ethereal energy and ethereal pressure, and so permits gravitation to aggregate larger masses. The occasional formation of stars of exceptionally large mass (20 to 80 times the sun's) may be due to the accidental prevalence of hydrogen in the region where they originated —that is to say, the material was in a more primitive state as regards evolution of the elements.

I do not think we need be greatly concerned as to whether these rude attempts to explore the interior of a star have brought us to anything like the final truth. We have, I think, been able to recognize some of the leading factors participating in the problem, and to learn how many varied interests are involved. The partial results already attained correspond well enough with what is observed to encourage us to think we have begun at the right end in disentangling the difficulties, and we do not anywhere come against difficulties which appear likely to be insuperable. The fact is that gaseous matter at very high temperature is the simplest kind of substance for a mathematical physicist to treat. To understand all that is going on in the material of this desk is a really difficult problem, almost beyond the aspirations of present-day science; but it does not seem too sanguine to hope that in a not too distant future we shall be able to understand fully so simple a thing as a star.

# FOSSIL MAMMALS AT THE COLORADO MUSEUM OF NATURAL HISTORY

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

In the year 1904 Mr. O. A. Peterson of the Carnegie Museum at Pittsburgh was looking for fossil mammals in Nebraska. In the month of July he visited Captain James H. Cook at his stock farm at Agate Spring. Shortly after his arrival, Mr. Cook's son Harold took him out to see a locality where fragments of bones were scattered on the surface. These bones had been noticed by the elder Cook as early as 1877, but supposed to be of no great consequence. Mr. Peterson proceeded to investigate and soon discovered that there was a rich deposit of mammalian remains of Tertiary age, a deposit which has since become famous as the Agate Spring Quarries.

It was fortunate for science that the Cooks were resident at Agate Spring. In other localities, paleontology has suffered severely from vandals, or has been hindered by stupid attempts at commercial exploitation. Captain James Cook, his wife and sons united with the utmost zeal and good will to render every possible assistance to those who were competent to open up and investigate their bone quarry, which proved to be one of the finest known. The eldest son, Mr. Harold Cook, was seventeen years of age when Mr. Peterson arrived. Entering into the spirit of the discovery, he soon became an active student of vertebrate paleontology. In the years 1907 to 1909 he attended the University of Nebraska and Columbia University, where he qualified as an expert geologist. Gladly encouraged by the older workers, he rapidly came to the front, and is now recognized as one of the authorities on the vertebrate life of the American Tertiaries.

The first species of mammal to be collected at the Agate Spring locality was apparently the large Chalicotheriid *Moropus,* which was obtained by Professor E. H. Barbour, of the University of Nebraska, July, 1892, twelve years before Mr. Peterson's visit. It was not until 1908, however, that this animal was named. Professor Barbour, in a publication of the Nebraska Geological Survey, called it *Moropus cooki.*[1]

[1] Holland and Peterson (1913) regarded *Moropus cooki* as a synonym of *M. elatus* Marsh, but Osborn (1917) considers it a valid species. The term *M. elatus* belongs to a later period.

In 1911 the American Museum of Natural History, with the cooperation of the Cooks, entered the field and during a number of years excavated numerous remarkably fine skeletons.

In 1916 a visitor to the Colorado Museum of Natural History at Denver, spoke to the director, Mr. J. D. Figgins, about the work at Agate. He had visited the place and was very much impressed by the discoveries made, and by the courtesy of the Cooks. Would not Mr. Figgins get in touch with them, and perhaps secure some of the materials for the Colorado Museum? The director accordingly went to Nebraska, and arriving at the spot asked whether arrangements could be made for his museum to excavate in some corner of the field. The generosity of the response astonished him. The fossils are overlaid by heavy sandstone, ten to fifty feet thick, which has first to be removed. At a certain place this arduous work had already been done, and a very fine lot of bones was exposed. Mr. Figgins was invited to help himself, and with suitable assistance secured the admirable specimens now exhibited in Denver. Thus, said Mr. Figgins, in describing the incident, Harold Cook is fairly to be called the father of our work on Tertiary mammals.

In former times, it had been a matter for regret that, although fossil vertebrates were so frequently found in the Rocky Mountain region, nearly all the specimens went to museums in the eastern states, or even to Europe. Colorado had never been willing to spend its money in excavating such specimens, or in building museums where they could be exhibited. This was not altogether surprising, for the state was comparatively new and poor, and the very profits made from her mines mostly went elsewhere, to swell the wealth of already rich groups of men. Yet, with the increase of population and the development of higher education, the point of view necessarily changed, and while we have not progressed very far, we are at least on the way to finer things. The city of Denver has established an excellent museum in one of its parks, supported mainly by municipal funds, after the manner of the American Museum in New York. In the center of the city is the State Museum, particularly noteworthy for its work in botany, but as yet receiving quite inadequate support. The Colorado Museum or City Park Museum, as it is often called, has many very fine mounts of mammals and birds, shown as in their natural haunts; but at present we are concerned with the fossils. Having got a fair start at the Agate Spring quarry, with the result of arousing a certain amount of interest in Colorado, it was natural that when Mr. H. D. Boyes, of Wray, Colorado, found some fossil bones, he should communicate with Mr. Figgins. Here, again, was the fortunate coincidence of a liberal and scientifically minded discoverer with a really first-class find. Wray is near the border of Yuma County,

FIG. 1. Excavating *Trigonias osborni*, a fossil rhinoceros; Weld County, Colorado (Oligocene).

only a short distance from the Nebraska line. Mr. S. N. Hicks has furnished an annual subsidy which has made it possible to keep a group of men in the field each summer. The find at Wray proved to be of much later date than that at Agate Spring. The numerous specimens, including two new species of the elephant group, a new sabre-toothed tiger, etc., have been studied by Mr. Harold Cook, who assigns them to the Pliocene. Thus, they are of special importance, as our knowledge of that period in our region has been very defective. Previous to the deposition of the stratum containing bones, the surface of the country has been eroded so as to remove all of the Eocene, Oligocene or Miocene deposits, exposing the Pierre (cretaceous) marine shales. Right on the surface of this is the thin Pliocene deposit, full of skeletal remains.

The Pawnee Buttes, high elevations standing isolated in the plains of Weld County, Colorado, represent the remains of a great Tertiary deposit. They have long been known to yield vertebrate fossils, but it has been supposed of late that nearly everything of value had been removed. This is evidently not the case, as Mr. Figgins had the good fortune to discover a ranchman in that vicinity, who, digging post-holes, had thrown out a fragment of bone. This

FIG. 2. Scene of excavations; Weld County, Colorado (Oligocene).

FIG. 3. Repairing large specimen in the museum.

FIG. 4. Slab of rock containing remains of the rhinoceros *Trigonias osborni*, from Weld County, Colorado, exhibited in the museum.

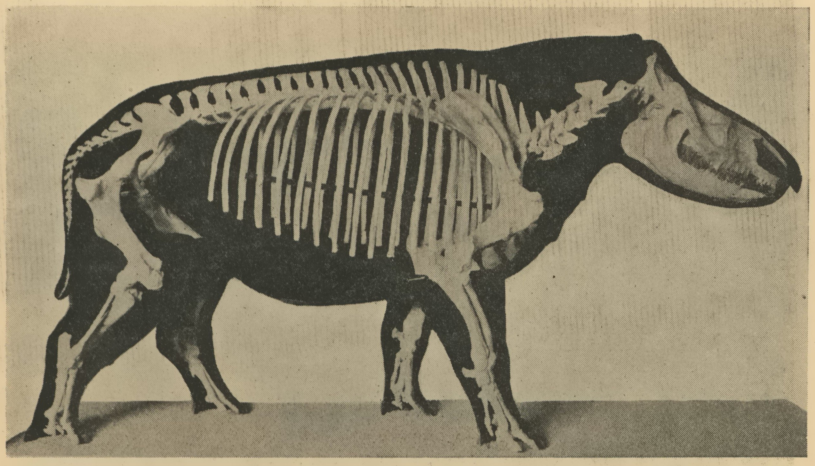


FIG. 5. Skeleton of *Trigonias osborni*, with restoration on other side.

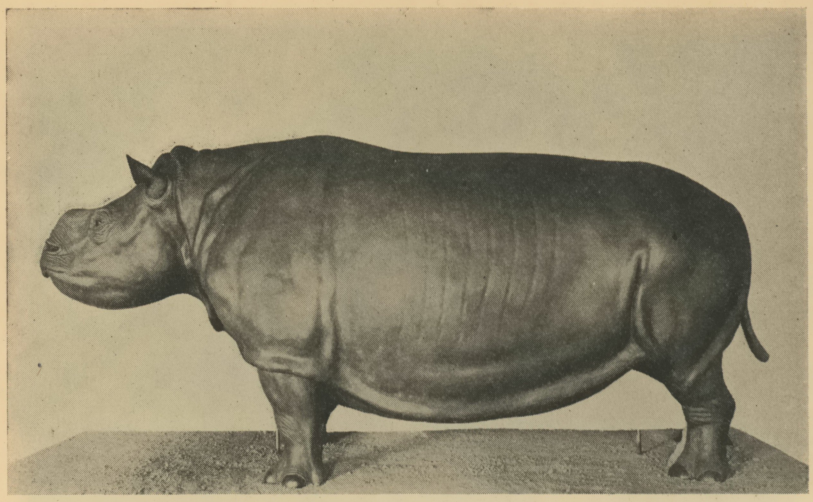


FIG. 6. Model of *Teleoceras fossiger,* another extinct rhinoceros, from Yuma County, Colorado.

suggested an excavation, and the result was that the Colorado Museum party unearthed splendid material of *Titanotherium.* Not far away the bones of *Trigonias,* a species of rhinoceros, were obtained; and further investigations resulted in finding a whole series of mammals of Oligocene age. It has not yet been possible to fully report on these, but it is at least known that this supposedly exhausted and well-known locality will yet add much to our knowledge of ancient life.

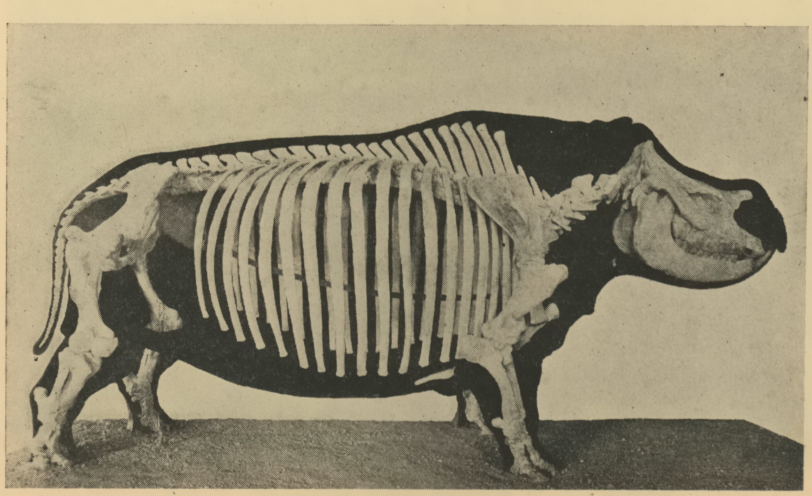


FIG. 7. Skeleton of *Teleoceras fossiger;* the other side is shown in Fig. 6.

Thus, by taking advantage of opportunities, with the aid of a few who could appreciate the potential educational and scientific gains, it has been possible to inaugurate a movement for the preservation and investigation of the remains of extinct vertebrates in Colorado, with facilities which are at least reasonably adequate. No one can doubt that the work will develop rapidly, as it has already done, and will at length assume very extensive proportions. Support will, we trust, increase with the opportunities arising from new discoveries, so that it may no longer be said that we must send our large fossils elsewhere from sheer inability to take care of them.

When the fossils have been found, dug out and brought to the museum, there is still a great deal to do in preparing them for exhibition. In the Colorado Museum the exhibits are so planned as to show how the fossils occur in the rocks and also the appearance of the animals in life. When I visited the museum last December, I was astonished to see what appeared to be a stuffed rhinoceros of a species quite unfamiliar to me. Going to inspect it more closely, I soon perceived that it was a model of half the animal (*Teleoceras*), the skeleton being exposed on the other side. It is exceedingly lifelike, and a more instructive exhibit could hardly be devised. In the preparation room I found large oil paintings, showing the country as it may have appeared in Tertiary times, with the various animals roaming about. These will be used as backgrounds for the exhibits of skeletons which are now being prepared and studied, some of them evidently representing animals new to science.

THE LATE PRESIDENT HARDING RECEIVING MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES IN APRIL, 1921

# THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

## A SELF-GOVERNING TURBINE

The wealth of Sweden lies largely in its water power. This amounts to about one and a fifth horsepower *per capita,* according to the calculations of Dr. Arrhenius, head of the Nobel Institute. Even the United States is not so rich in hydraulic resources in proportion to its population and is not yet making as much use of what it has.

The Swedes have broken to harness one quarter of their wild waterfalls and are preparing harness for those that are still running at large. They are not afraid of a coal famine, for they have always had one. From their wood and waterfalls they can get both heat and power, and they are making every effort to be as independent as possible of those countries which have inherited their wealth from the Carboniferous Epoch.

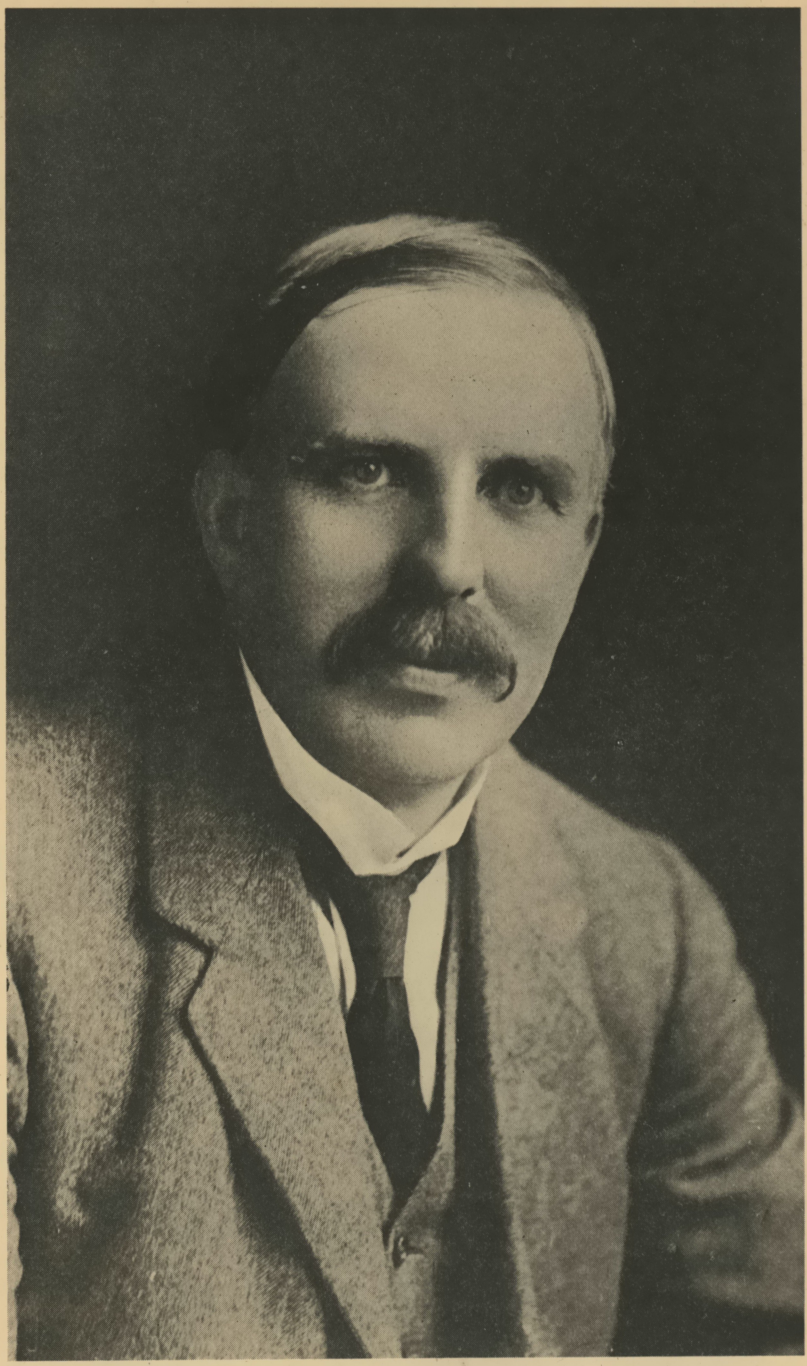
I never realized how many Swedes had wheels in their heads till I entered the Machinery Hall of the Gothenburg Jubilee Exhibition where their new inventions are displayed. There were turbines on every side and overhead. Turbines for water; turbines for steam; turbines for milk. Turbines three times as tall as I was and turbines that I could hold in my hand. It seemed that the spirit of De Laval had inspired the nation.

Among these various turbines were some of novel and curious form. One I took for a ship's propeller, instead of a water wheel, for it had only three blades and no rim. On inquiry I found it was called the Kaplan turbine and was just being developed in Sweden.

In order to secure the greatest efficiency as a power producer a turbine has to be constructed so as to run at a certain speed under a given head of water. But when the load, speed, flow or pressure changes, the turbine does not work so well as one of a different design would. To overcome this difficulty Professor Kaplan, of Brunn, has invented a waterwheel with adjustable blades and guide vanes which are automatically shifted to a different angle by a sensitive governor so as to secure the greatest possible efficiency whenever the conditions change. In this turbine the blades are reduced to four or three or two and are made short and broad, being so set as to pass the water through in a continuous positive eddy without reverse currents anywhere.

A turbine of the Kaplan type is now being constructed by the Kristinehamn works for the Royal Swedish Waterfall Board to be installed at Lilla Edet. In this a single wheel of 19 feet diameter, weighing 62 tons, will give 10,000 horsepower under a head of 22 feet, and can take an overload of twelve per cent. Its specific speed is 640.

The specific speed is the number of revolutions per minute that a similar turbine would make if of such a size as to give one horse-power under a unit head of water, which in the European system is one meter. The higher the speed, the less the efficiency, as a rule, but it is claimed for the Kaplan turbine that it will show an efficiency of more than eighty



SIR ERNEST RUTHERFORD

Cavendish professor of experimental physics at the University of Cambridge; President of the British Association for the Advancement of Science, meeting this month at Liverpool.

per cent. with a specific speed of over 800, a considerable gain over the speeds of 300 or 400 formerly customary. A recent installation of a Kaplan turbine shows an efficiency ranging from 84 to 86 per cent. with the horse-power varying from 57 to 99, and a specific speed of 718, the highest yet attained in Scandinavia. The conical construction of the outlet pipe, whether straight or bent, produces a suction below the wheel that adds to its power.

But its self-governing ability was what interested me most. If I slowed up the wheel of the model by the touch of my hand it adapted itself to the new condition as quickly as a gyroscope top when it is tipped. It was indeed a model—to human beings who often wobble and creak badly when their equilibrium is disturbed and waste much time and energy before adjusting themselves to changed conditions of load or motive power.

## SCIENCE AS A RECREATION

Most people think of science as a serious and solemn thing, a strain upon the strongest intellect. So it is for the pioneers of scientific progress, but not for those who merely follow along behind.

The layman does not exaggerate, in fact, he does not begin to appreciate, the difficulty of original research, the devotion and self-sacrifice of men of science. A man may pursue a subject for years and then find that he has lost his labor through taking the wrong turn in the labyrinth of nature. He may count himself one of the fortunate if what he accomplishes in a lifetime is considered worthy of filling a footnote in some general compendium of science.

But however painful and slow a process may be the promotion of science, its results are intended to eliminate labor and economize time. The scientist toils that others may have an easier time. It is owing to the labors of a long line of electricians from Faraday to Bell that the housewife is able to telephone the grocer to send over the ice cream for dessert. If mechanics from Hero, of Alexandria, to Otto, of Germany, had not worked over engines we should not be able to take a hundred-mile ride in an auto any fine day.

Science is a thought-saving device and when applied to life it results in time-saving and labor-saving inventions.

Science means simplification. It substitutes a single rule for a million miscellaneous observations. To borrow a phrase from Poincaré, science consists in giving the same name to different things. The scientist links things together by whatever they have in common. If you have a lot of loose papers to carry, or sticks of kindling wood, you will do it easier if they are tied together in a single bundle. That is what the scientist is always doing, tying up fugitive facts into compact and portable packages. Learning the 36 combinations of the multiplication table is hard work, but once you have mastered them you become master of all the multiplications in the world. Newton's law, "Action and reaction are equal and opposite," covers in seven words all possible cases of the application of force.

Because some people have to study the sciences seriously, it is no reason why the rest of us should not chat about them or joke about them. We may make light of ponderous matters and even treat gravity with levity without danger of irreverence.

## A NEW PATH TO OBLIVION

It is within the memory of many still living that science revealed to mankind means of escape from the pains of disease and surgery. Nitrous oxide and ether were used for amusement long before they were used for relief. Medical students in New England used to take laughing gas or indulged in "ether frolics" for the fun of the thing without thinking of the possibilities of applying it in their profession.

But in 1844 a Connecticut chemist named Colton had a big back tooth pulled out after inhaling nitrous oxide and two years later, Dr. Morton, a Boston dentist, put himself to sleep with ether and then tried it on a patient who came into his office as he awoke. The use of anesthetics was bitterly opposed at first on the ground that pain was a punishment or a natural process and that it was cowardly or wicked to evade it, but the new practice prevailed and brought surcease of suffering to uncountable millions of men. women and children in the last seventy-five years.

Nitrous oxide and ether have been the chief means of producing complete unconsciousness, but now a new agent of anesthesia has entered the field that promises to rival or supplant both. This is ethylene, a gas composed of hydrogen carbon, long in use for illuminating, but which has recently been found by Professor A. B. Luckhardt, of the University of Chicago, to have the power of putting a person to sleep without the danger and unpleasant after-effects that sometimes attend the use of the older anesthetics. On inhaling the gas the patient passes quickly into insensibility and then into complete unconsciousness. The respiration and blood pressure remain regular and the muscles are relaxed. The recovery is remarkably rapid. Within three or five minutes the patient comes to his senses, usually without nausea. In the case of a severe operation on the leg the patient had to be kept under the influence for three hours and ten minutes continuously. Yet five minutes afterwards he had become conscious, got off the operating table himself and two hours later ate a meal.

In the four months that the new anesthetic has been in use at the Presbyterian Hospital in Chicago some 350 operations of all sorts have been successfully performed under its influence. A Chicago dentist has extracted teeth from about a hundred patients using ethylene in place of nitrous oxide. It has also been found useful in normal childbirth.

The discovery of the soporific effect of ethylene came through a curious chain of circumstances. In 1908 the carnation growers complained that they were losing money because the flowers they shipped to Chicago went to sleep when put in the greenhouses and the buds failed to open. A couple of botanists from the University of Chicago were assigned to the job of running down the reason of this floral "sleeping sickness" and found that it was due to the leakage of illuminating gas which contained four per cent. of ethylene. This is commonly added to city gas to increase its candle power. Plants are extremely susceptible to ethylene. Sweet peas will droop their leaves if the room contains one part of ethylene in a million of the air; a much more delicate test for its presence than any chemical reaction. This may be a reason why plants do not thrive and people get sleepy in houses where the gas fixtures are leaky.

Since the investigation now led out of the vegetable kingdom and into the animal it passed over into the hands of the physiologists who carried the experiments on up the scale of life, using frogs, mice, rats, guinea-pigs, rabbits, kittens and dogs successively as subjects. It was found that

ethylene brought the animals into unconsciousness in half or a quarter of the time necessary for nitrous oxide and that they recovered more quickly.

Finally Dr. Luckhardt and his colleague, Mr. Carter, having thus assured themselves of its safety and learned how to administer it, tried it on themselves and for several successive Sunday afternoons put themselves to sleep by the inhalation of ethylene. They have both been anesthetized a dozen times since without noticing any untoward symptoms.

The gas is inhaled with oxygen as is the custom with nitrous oxide. Between 80 and 90 per cent. of ethylene is sufficient in most cases to bring the patient to the point where a surgical operation may be carried on. Care must be taken of course to see that the gas is pure and also to keep it away from flames since ethylene, like ether vapor, is inflammable.

The brief history of ethylene as an anesthetic is a striking illustration of the acceleration of scientific progress in this century. In 1798 Humphry Davy, then only 22, discovered nitrous oxide and suggested that it might be used to stop the pain of surgery, but it was half a century before this hint was acted upon, fifty years of unnecessary pain and loss of life. But in the case of ethylene the progress from pinks and peas to professors and patients was made with swift sure steps and in the course of a few months humanity was receiving relief from this new source.

When it was proposed to erect in Boston a monument to the discoverer of anesthesia, a hot discussion took place as to who was entitled to the honor. Should it be Dr. Morton, who pulled the first tooth with ether, or Dr. Jackson, who told him how to use it. Dr. Oliver Wendell Holmes then suggested that the statues of both claimants be put on one pedestal inscribed "To Ether." This is one of the jokes that no Englishman can understand, for he would pronounce it "eye-ther."

If ethylene proves to be as useful as it seems to be, room must be found on the same pedestal for Dr. Luckhardt, even though it spoil the pun.

## CATCHING UP WITH CHINA

We Americans may be a little slow in catching on to old ideas, but once we do get them we push them for all they are worth.

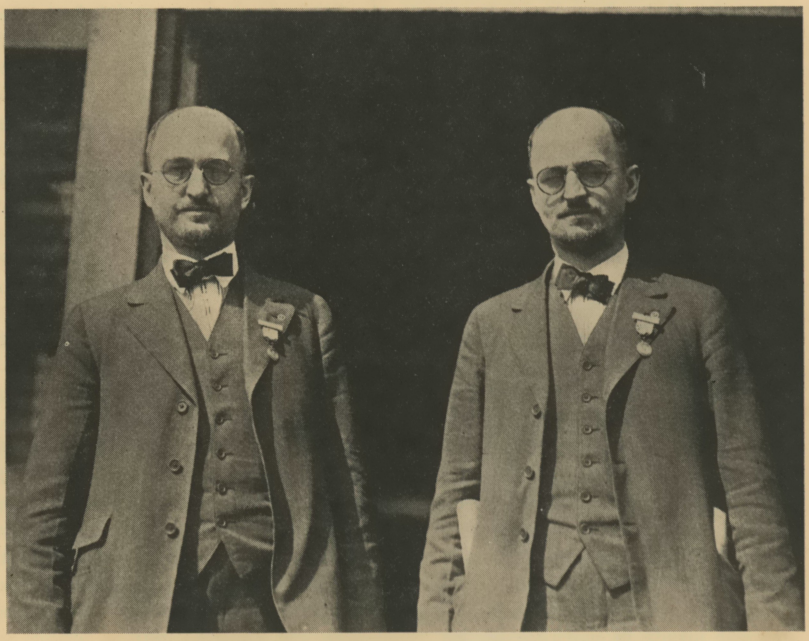
Take the soy bean, for instance. That was first introduced to America in 1804, but it was a hundred years before we could be induced to take it seriously. We started in therefore five thousand years behind China and Japan in the cultivation and use of the soy bean, for there it ranks next to rice. But in the last ten years it has rapidly come to the front as one of our major crops and it is likely in the next ten years to go ahead of oats in acreage in some of our states. Wherever corn or cotton flourishes the soy bean can be grown, and few crops have so many strings to their bow. The latest bulletin of the Department of Agriculture lists fifty different uses for soy products, and doubtless Yankee ingenuity can and will add more when we get our minds to working on it.

Even the Japanese have not exhausted their ingenuity in this field, long as they have been at it. A Japanese scientist named Sato has invented a new plastic which he has called, according to American precedent, "Satolite." It is made by precipitating the protein with sulphite, hardening it with formaldehyde, and molding it under heat and pressure into combs, buttons and whatever we make from hard rubber or celluloid or the casein of milk.

The soy bean is rich in protein and fat, and lacking in starch; in that more like animal than like vegetable food. You can make a milk out of it by simply soaking the dried beans till soft, then crushing fine in a meat grinder, boiling in three times the volume of water for half an hour and straining through a cloth. If you do not like the flavor you can add vanillin or something else. This vegetable milk sometimes agrees with children when cow's milk does not. It can also be used for cakes and custards.

The soy milk may be made into curds and cheeses of various sorts which form a large part of the diet of orientals, but for which we have not yet acquired a taste. Soy meal has come into common use in America, not only as a cattle food, but also for bread and pastry mixed with three parts wheat flour.

Soy sauce has long been familiar but quite unknown to us. We did not recognize it under its aristocratic English name and its added flavors. But when the high cost of living drove us to the chop sueys, we became acquainted with the cruet of brown salty sauce called "shoyu," and we found, as the Chinese had found thousands of years before, that a sprinkling of it would make tasty a large lot of rice and serve as substitute for meat, both in taste and nutriment. Soy sauce is of several sorts. If you want it strong take the Korean. If you want it sweet take the Japanese.



*—Wide World Photos*

DRS. W. C. AND W. H. TUCKERMAN

Twin brothers who practice medicine in partnership at Cleveland, Ohio. Though known to practically every delegate attending the convention of the Ohio State Medical Association, Drs. W. C. and W. H. Tuckerman, twins of Cleveland, Ohio, caused confusion among the visitors by their almost identical dress and personal appearance. Both doctors practice together.

It is made by fermentation and the flavor depends upon the way it is brewed and the length of time it is left to ripen. To suit the palate of a Korean connoisseur the jars must be exposed to the sunshine by day and covered by night for a period of thirty years. We Americans, when we get to making it, will undoubtedly speed up the process.

So far the oil is the most in demand of the soy products. The beans contain from 18 to 20 per cent. of a fine palatable oil, which we have imported at the rate of a hundred thousand tons in a year, but which we are now growing for ourselves. It can take the place in part of cotton-seed oil in vegetable substitutes for lard and butter, and of linseed oil in paints. Formerly the oil went mostly to Germany and England, but the war made a shift in the currents of Pacific trade, and we learned to appreciate its value. But we have a lot to learn yet before we catch up with the orientals in the utilization of this multifarious bean.

**PHOSPHATES AS STIMULANTS**

During the war we heard all sorts of wild rumors about the German soldiers being given some secret chemical that endowed them with supernormal energy as they charged the trenches or endured forced marches. Doubtless various things were tried, including that old and unreliable stimulant, alcohol, and the newer and less exciting energizer, sugar.

But it has now been disclosed that most remarkable results in the increase of muscular power and endurance were obtained from the use of a well known salt, called by the chemist "sodium dihydrogen phosphate." This was given to the shock troops as they entered battle or during long marches in the form of a drink. To avoid the influence of psychological suggestion, which has invalidated so many tests with "poison squads" and experimental subjects, other battalions were served with a sham drink sweetened and flavored the same, but acidulated with tartaric instead of phosphoric acid. At the end of a hard hot day the troops that had been treated with the phosphate were fresher in spirit and less fatigued in body than the others for some reason mysterious to them.

Since the war it has been found that giving phosphate drink to coal miners and farm laborers increased their monthly output without extra exertion. Horses and oxen given an ounce of the salt a day did more work and gained flesh. Here there could be no deception due to the imagination.

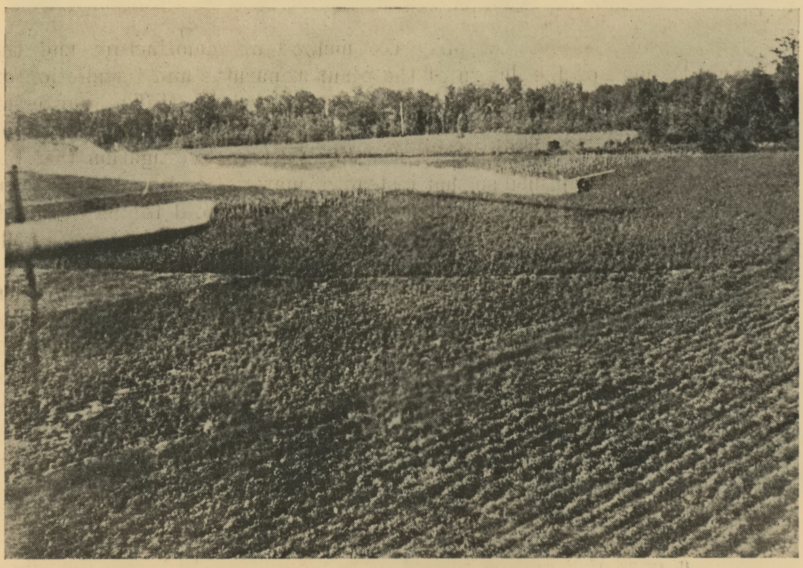
This practical and promising method of increasing human and animal efficiency came from the investigations of one of the foremost of German physiologists, Professor Gustaf Embden, of Frankfort University, on the chemistry of nutrition. According to this theory muscular energy comes from the breaking down of a substance called "lactacidogen," which he regards as a compound of sugar and phosphoric acid. This breaks down, when the muscle contracts, into lactic acid and phosphoric acid. Lactic acid, as it has long been known, accumulates in a fatigued muscle and has to be recombined or oxidized before the muscle can work again. So Embden reasoned that adding phosphate to the diet would hasten the combination of the phosphoric acid with more sugar and so relieve the fatigue. The war gave him the chance to experiment on whole regiments at a time and the results seem to confirm his theory.

The new stimulant has the advantage over alcohol or the alkaloids in that it is a natural factor in bodily process, and also in that there is no danger of intoxication from an overdose or of forming a habit. Doses up to a quarter of an ounce a day were given to the soldiers and laborers.

*—Wide World Photos*

EXPLORING BY AEROPLANE

The 1923 Franco-American Expedition exploring the ruins of Carthage under the leadership of Count Byron Kuhn de Prorok, Prince Edgard de Waldeck, who was killed in a motor accident at Juan les Pins on his return from Carthage, acting as observer in the airplane piloted by Lieutenant Peletier d'Oisy. In this flight they traced an under water sea wall and saw columns still standing 100 yards off the shore. They also searched for a wrecked galley of Punic time in the Gulf of Tunis.



*—Wide World Photos*

SPRAYING COTTON FROM AEROPLANES

Experiments are being made by the army at Tallulah, La. The dusting plane flies at an elevation of about 25 feet.

More than this, and sometimes much less than this, has a laxative effect.

The report of these experiments is likely to multiply calls for phosphate drinks at the soda fountains, but the anticipated increase of muscular vigor may fail to be felt, for when the man behind the marble counter mixes a phosphate he throws in a dash of a very dilute solution of phosphoric acid, and a person would have to take some fifty such drinks to get the amount used by the soldiers.

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## INTARVIN

*Science Service*

The invention of a new form of artificial fat that can be digested by diabetic patients was announced by Dr. Max Kahn at a meeting on August 2 of the medical staff of the Beth Israel Hospital, New York City.

At that hospital feeding with the new fat has given relief in thirty cases of acidosis due to diabetes. One man was carried into the hospital for the purpose of having his leg amputated since it was attacked with gangrene. But after the artificial fat had been added to his diet the acidosis was stopped, the sores healed up and four weeks later the man walked out of the hospital on his own two legs.

Dr. Kahn, who has charge of biological chemistry in the College of Physicians and Surgeons of Columbia University and of diseases of metabolism at the Beth Israel Hospital, has been working for a year and a half to make a fat that would not break down into acid products as do natural fats in cases of diabetes. From recent researches in the chemistry of nutrition he came to the conclusion that a fat with an odd number of carbon atoms would serve the purpose. But such a fat could not be found in nature so it had to be made to order.

The investigations to simplify the method of manufacture and the carrying through of the design of the plant apparatus and installation of equipment have been conducted by Professor Ralph H. McKee, professor of chemical engineering, Columbia University, and required the services of two assistants for six months. It was through this investigation that the process has been simplified so that instead of material costing $300 or even $100 a pound, it can now be made in a factory and sold for $8 a pound, and probably this cost will decrease still more once production is well under way. A pound will last a patient from a week to three weeks.

A manufacturing plant has been built in Long Island City and 200 pounds of the new product is turned out in a week. It has been named "intarvin," meaning "intermediate fat" because the molecule contains 17 carbon atoms and is therefore intermediate in composition between the ordinary fats carrying 16 and 18 carbon atoms.

Intarvin is a white crumby substance, tasting something like tallow but is not so soft. It is either eaten straight or mixed with a little tasteless mineral oil or made up into a mayonnaise or shaken up with buttermilk or baked in gluten bread. The diabetic patients find the new fat quite eatable and it satisfies the craving for fat common in the disease.

It is a curious coincidence that within the year 1922 two remedies, Insulin and Intarvin, have been invented for diabetes, which, though one of the most common and serious of diseases, has hitherto baffled medical skill. Insulin, which was discovered by Dr. F. G. Banting, of the University of Toronto, is an extract of animal pancreas which when injected into the veins restores temporarily the power to assimilate sugar. Intarvin is a synthetic fat which is assimilable by diabetics in whom natural fats produce an excess of acid. Neither insulin nor intarvin is regarded at

present as a permanent cure for diabetes, but both restore temporarily the digestive powers, the former for sugars, the latter for fats, but each increases somewhat the ability to handle the other types of food.

After preliminary experiments on animals the new treatment was tried first on a diabetic woman of 47 who had been in the hospital a year awaiting an operation for tumor, but she was so run down that it was not thought safe to operate. She was put on a fat-free diet to free her system from the injurious acids, but these still continued to be formed from the body fats. When a few ounces of intarvin was added to the diet the excess of acids and sugar disappeared within forty-eight hours. She has since been kept free from acidosis for 14 months by use of the intarvin fat.

Acidosis may be caused by starvation as well as by diabetes, so the next experiment was tried on a normal man. A young Swedish prize-fighter was induced by a pecuniary consideration to go without food for 74 hours. It was then found that he was excreting the acid products of unassimilated fat. But when he was given four ounces of the artificial fat mixed with the same amount of seven-times boiled string beans his digestion next day was normal. But when he took butter with the beans he was not able to digest it. Of the artificial fat 95 per cent. was digested.

Here is a case of the use of "high brow" science. The discovery of this new treatment for diabetes comes from the study of the structure of the fat molecule and how it breaks down in the body. The molecule of a fat consists essentially of a long chain of carbon atoms connected together. The number of carbons varies with the fat, but is always an even number in natural fats. In stearic acid, for instance, which is the principal constituent of beef tallow, there are 18 carbon atoms in the chain. All of the carbons carry hydrogen atoms attached, except the carbon atom at one end of the chain which carries oxygen.

When a fat is burned up in the body to provide heat and energy, it is the oxygen end of the chain that is first attacked. Two carbons at a time are broken off until the whole molecule is reduced to carbon dioxide and water. Starches and sugars are normally burned, that is, oxidized, to the same harmless products.

A diabetic patient can not digest sugars and starches and so is forced to draw upon fats for his nutriment. But he can not completely break down the fat molecule. Instead of reducing it to its lowest forms, carbon dioxide and water, he can only cut down the chains to four carbons, which leaves in the body a pernicious compound known as aceto-acetic acid. This condition is known as acidosis. The presence of such acids prevents the blood from carrying off the waste carbon dioxide to the lungs for elimination, and the patient finally sinks into a state of coma, followed by death.

Since the carbon chain breaks down two at a time, it would follow that a fat molecule containing an odd number of carbons could not break down so as to leave the chain of four carbons that form the harmful acids.

This is the theory on which Dr. Kahn and Dr. McKee have worked. Starting with beef tallow they get out the stearic acid which contains 18 carbon atoms in its molecule. Then by oxidation they cut off one carbon atom from the chain leaving 17, a compound known to chemists as margaric acid. This is then recombined with glycerine forming a neutral fat, which, as the hospital tests have shown, can be digested by diabetics.

Neither margaric acid nor any fatty acid with a long chain of an odd number of carbon atoms occurs in any natural fat or oil. Some such compounds have been made in the laboratory but only a gram or so has been produced as a chemical curiosity. This is the first time that a purely artificial food has been manufactured in hundred pound lots for use as a regular article of diet.

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